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ABSTRACT

This document consists of activities and references for teaching astronomy. The activities (which include objectives, list of materials needed, and procedures) focus on: observing the Big Dipper and locating the North Star; examining the Big Dipper's stars; making and using an astrolabe; examining retograde motion of Mars; measuring the Sun's diameter; finding the Sun's altitude and azimuth; observing sunspots; examining sunspot numbers over time; classifying stars; using a model to demonstrate the expanding universe; and making a moon phase model. The references include: a list of suppliers for audio-visual aids used in teaching astronomy; descriptions (and sources) of star charts and telescopes; an annotated list of astronomy periodicals; a list of professional astronomy organizations; articles by John Percy (including "Astronomy in the Classroom--Some New Resource Material," "Astronomy in Your Classroom", "Education in Astronomy: A Review," and "The Teaching of Astronomy in Canadian Schools"; several additional articles, including "Readily Observable Phenomena" by Dave Berryman, "The Mysterious Satellites of Saturn" and "Jupital Watch Continues--Jupiter Revealed" by Chandra Madhosingh, and "How to See the End of Night as the World Turns" by Allan Wooton; sky charts; a description of teaching styles related to astrological signs; and other materials. (JN)

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ASTRONOMY ACTIVITIES

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TO THE INSERVICE PARTICIPANTS:

The following booklet is presented to you in conjunction with a workshop on astronomy.

This booklet was designed as a hands-on approach to the field of astronomy. The focus is methodology coupled with essential theory. Our aim is to provide you with the materials you need to teach an astronomy unit to your students as well as suggested procedures, activities and ideas. Astronomy fact sheets have been gathered for you and are interwoven into each activity.

I hope that this inservice will be useful to you and to your students.

Thank you for your interest. If you have any questions and/or comments please, do not hesitate to contact me.

Yours truly,

Sid Greenstone
Sid Greenstone

PS: I can be contacted at the following place:

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Science Museum of Virginia

OBSERVING THE BIG DIPPER AND LOCATING THE NORTH STAR

OBJECTIVE: After completing this activity, the student should be able to identify the Big Dipper and locate the North Star in the sky on any clear night.

MATERIALS: Star map of north polar region (included), tracing paper

OTHER REQUIREMENTS: The student is required to observe the northern sky on several clear evenings.

One of the easiest star patterns to recognize is the Big Dipper, which serves as a convenient guide for locating the North Star. The Big Dipper is a part of the constellation URSA MAJOR (the Great Bear). Most or all of the Big Dipper is visible above the northern horizon on any clear night throughout the continental United States.

The North Star (Polaris) marks true north (within one degree) and can be used for estimating the latitude. It is the end star in the handle of the Little Dipper and has served for many years as a navigational aid.

PROCEDURE: Refer to the star map of the north polar region included herein.

A. Identifying the Big Dipper

1. Find the Big Dipper on the star map. The Big Dipper is a star pattern which is part of a larger group of stars that forms the constellation of URSA MAJOR.

2. As the earth rotates, the Big Dipper changes its orientation in the sky. To locate the Big Dipper it is necessary to be able to recognize its pattern in various orientations. To do this, first place a sheet of tracing paper over the star map.

3. Draw two tracings, side by side, of the <u>dots only</u> of the Big Dipper near the left edge of the tracing paper.

4. Leave the first tracing as dots only, but draw the connecting lines in the second tracing to show the outline of the Big Dipper.

5. Rotate the star map counterclockwise ¼ turn.

6. Draw two more closely spaced tracings of the Big Dipper to the right of the previous tracings.

7. Again, connect the dots of the second tracing to show the outline of the Big Dipper.

8. Rotate the star map an additional ¼ turn counterclockwise (½ turn from the original position).

9. Repeat steps 6 and 7.

10. Rotate the star map an additional ¼ turn counterclockwise (3/4 from turn from the original position).

11. Repeat steps 6 and 7.

12. Study and memorize the stars and lines of the Big Dipper. Learn to recognize the Big Dipper in various orientations.

13. On a piece of scratch paper, draw the dots and lines of the Big Dipper without looking at your tracings. Repeat this until you can draw the patterns from memory in any orientation. You are now ready to locate the Big Dipper in the night sky!

14. Homework: Observe the night sky tonight or on the first clear night. Try to locate the Big Dipper by looking in the northern sky.

15. Sketch the Big Dipper as you see it in the sky. Record the date and time on your sketch.

16. If possible, observe and sketch the orientation of the Big Dipper several times during the night, recording the times of observation.

17. Discuss the results of your efforts in class.

B. Locating the North Star (Polaris)

1. Many of the bright stars have been given names by the early astronomers. Several are identified on the star map. Find the two stars, Merak and Dubhe, in the bowl of the Big Dipper.

2. Follow an imaginary straight line from Merak through Dubhe until it reaches Polaris. Polaris is also called the North Star, since it is within one degree of the north celestial pole (the point directly above the north end of the earth's axis of rotation). Merak and Dubhe are known as the Pointer stars.

3. Polaris is the end star in the pattern of stars known as the Little Dipper. The Little Dipper is a part of the constellation of URSA MINOR (the Lesser Bear). Find the Little Dipper on the star map.

4. Repeat the procedure of tracing the stars of the Little Dipper as given in Step 3 through 13 for the Big Dipper.

5. Homework: On the first clear night, locate the North Star by drawing an imaginary line through the Pointer stars in the Big Dipper until it reaches Polaris.

6. The stars in the Little Dipper are fainter than the stars of the Big Dipper. If your observing site is sufficiently dark, you should be able to recognize the Little Dipper. Sketch the Big Dipper and Little Dipper as you see them. Label the North Star and record the date and time.

7. If possible, observe and sketch the orientation of the Dippers several times during the night, recording the times of observation.

8. Discuss the results of your efforts in class.

APRIL EVENING
TOP AFTER ½ TURN

JANUARY EVENING
TOP AFTER ¼ TURN

JULY EVENING
TOP AFTER 3/4 TURN

OCTOBER EVENING
TOP FOR 1st TRACING

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THE BIG DIPPER IN 3-DIMENSIONS

OBJECTIVES: After completing this activity, the student should be able to:

1. state that the stars of the Big Dipper are at various distances from the Earth, and

2. demonstrate the change in appearance of the pattern formed by the stars of the Big Dipper when viewed from different points in 3-dimensional space.

MATERIALS: Aluminum foil, sheet of cardboard (approximately 21 x 28 cm.), string (180 cm.), ruler, pencil, tape, pin (or compass point), table of coordinates and distances for stars of the Big Dipper (included).

OTHER REQUIREMENTS: The student can complete this activity within one hour in a classroom.

The stars in the night sky are at various distances from the Earth. Some stars are near neighbors (less than 20 light years away) while others are at much greater distances. As a result, the familiar star patterns and constellations that are recognized from Earth, will appear quite differently from other locations in our part of the galaxy. A 3-dimensional model of the Big Dipper will illustrate this point.

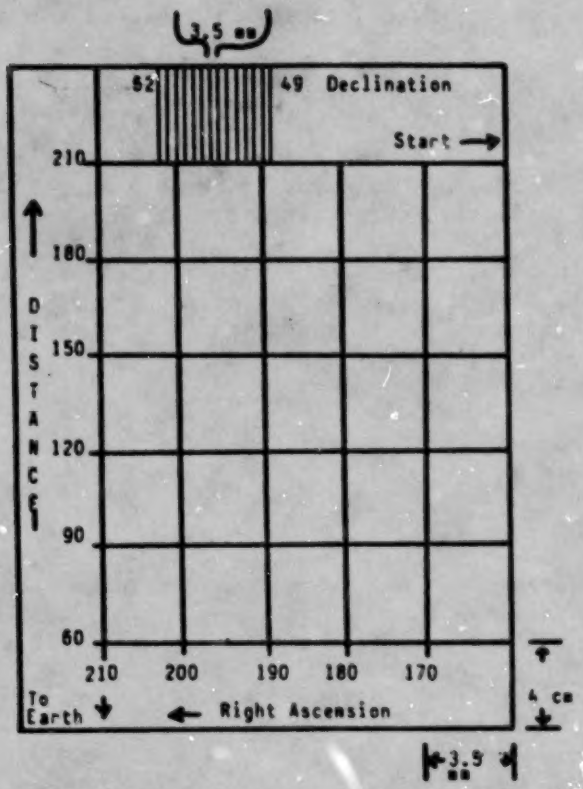
PROCEDURE: A 3-dimensional model of the Big Dipper can be constructed by using the table of coordinates and distances included herein.

1. Roll strips of aluminum foil into seven small beads to represent the stars of the Big Dipper.

2. Cut string into seven equal pieces, each 25 cm. in length.

3. Tie an aluminum bead securely to one end of each piece of string. Set aside.

4. Prepare the cardboard sheet according to the pattern shown:



Drawn to 1/3 scale

5. Right ascension is one coordinate used to locate a star in the sky. Here the right ascension scale increases from right to left along the bottom edge of the cardboard. The right ascension is expressed in degrees in the table.

6. Declination is the other coordinate used to locate a star in the sky. The declination of the stars in this model will be set by adjusting the length of each string, using the scale at the top edge of the cardboard. Declination is also expressed in degrees.

7. Distance to the stars is expressed in light years. One light year is the distance light travels in one year (186,000 miles/sec x 60 sec/min x 60 min/hr x 24 hr/day x 365¼ days/yr = 5,870,000,000,000 miles). The distance from the Earth increases from bottom to top along the left hand edge of the cardboard.

8. Locate the position of each of the seven stars of the Big Dipper on the cardboard sheet by referring to its right ascension and distance given in the table. Place an 'x' at the position of each star and label with the star's name.

9. Use a pin or compass point to punch a hole through the cardboard at the location of each star.

10. Mark each string to correspond to the declination of each star. To do this, place the aluminum bead at the edge of the cardboard marked 'Declination Start.' Stretch the string along the upper edge of the cardboard and put a mark on the string corresponding to the declination of the star.

11. Thread each string through the proper hole in the cardboard from underneath, so that the aluminum bead hangs suspended under the cardboard sheet. Adjust the length of each string so that the mark corresponding to the star's declination is even with the hole in the cardboard. Tape the string in place.

12. When viewed from the Earth's direction, the stars should form the familiar pattern of the Big Dipper.

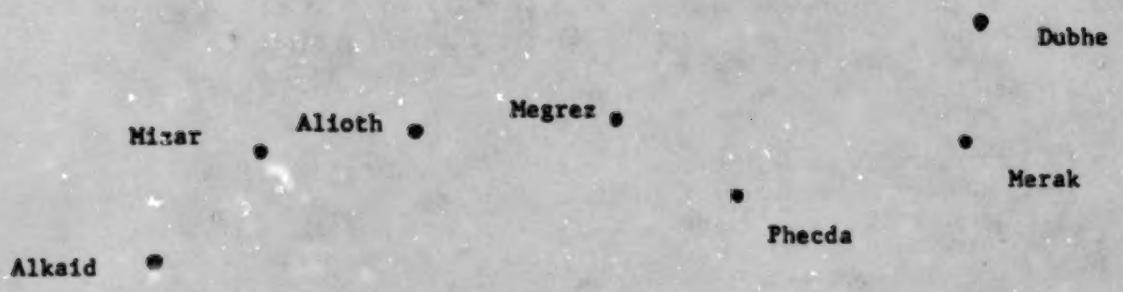
13. Notice how the pattern changes when viewed from other vantage points in space.

14. Discuss the effect this may have on interstellar space travel (journeys among the stars).

15. What names might be given to this group of stars when viewed from other directions?

TABLE OF COORDINATES AND DISTANCES

FOR STARS OF THE BIG DIPPER



Star	Right Ascension	Declination	Distance (L.Y.)
Alkaid	207°	49°	210
Mizar	201°	55°	88
Alioth	193°	56°	68
Megrez	183°	57°	63
Phecda	178°	54°	90
Merak	165°	57°	78
Dubhe	165°	62°	105

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MAKING AND USING AN ASTROLABE

OBJECTIVES: After completing this activity, the student should be able to:

1. describe how to make an astrolabe, and
2. demonstrate the use of an astrolabe for measuring the altitude of any celestial object.

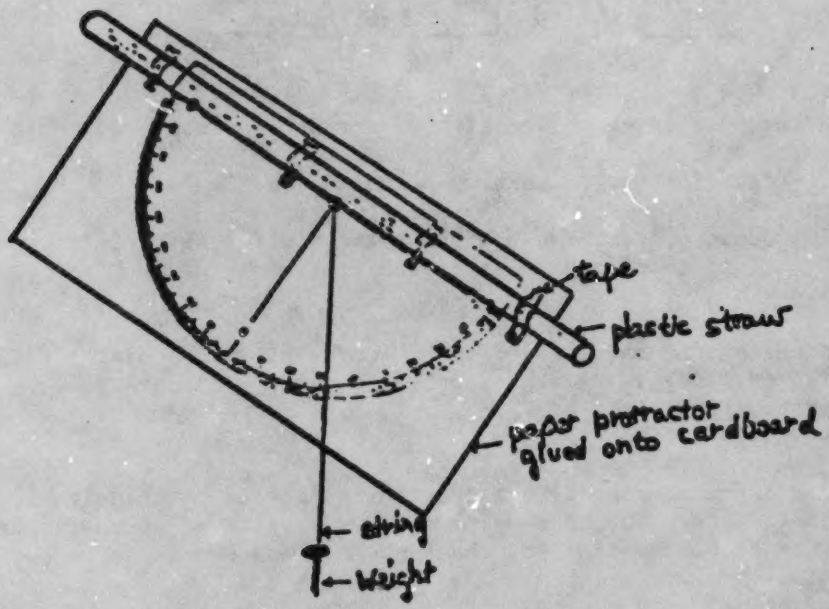
MATERIALS: Sheet of cardboard (12 cm. x 20 cm.), plastic straw, string (25 cm. long), a weight (such as a washer, nut or nail), paste, tape, scissors.

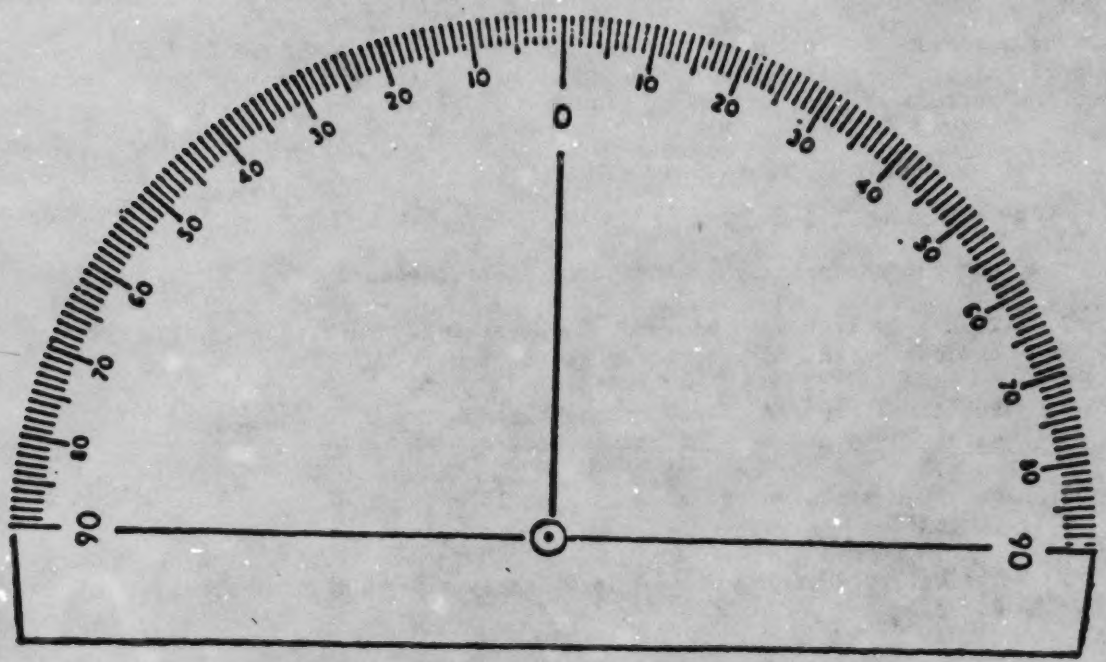
OTHER REQUIREMENTS: The astrolabe can be constructed and tested in the classroom in less than one hour. The activities for use of the astrolabe require observations of the Sun, Moon and stars over a period of several weeks.

The astrolabe is an instrument used to measure the Altitude (height above the horizon) of any celestial object. Much useful information can be learned about the motions of the Sun, Moon, planets, and stars using an astrolabe.

PROCEDURE:

1. Cut out the protractor and paste it to the cardboard.
2. Tie the weight onto one end of the string. Punch a hole through the cardboard and protractor at point marked ⊙ .
3. Put the loose end of the string through the hole and tape it securely to the back of the cardboard.
4. Tape the straw so the edge is exactly along the edge of the protractor.
5. The weighted string should hand freely along the protractor. See diagram.


tape
plastic straw
paper protractor glued onto cardboard
string
weight


0
10
20
30
40
50
60
70
80
90

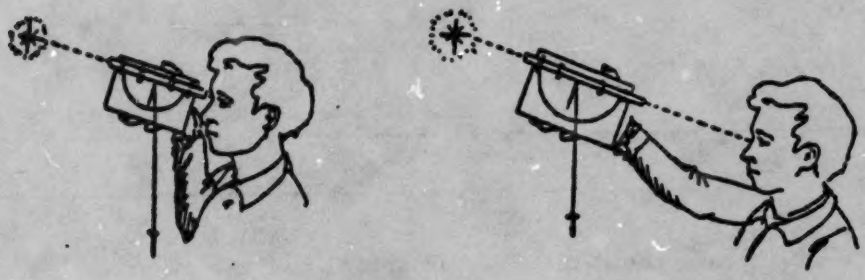
PROTRACTOR

INSTRUCTIONS FOR USING YOUR ASTROLABE:

To measure the altitude or the height above the horizon of a star--

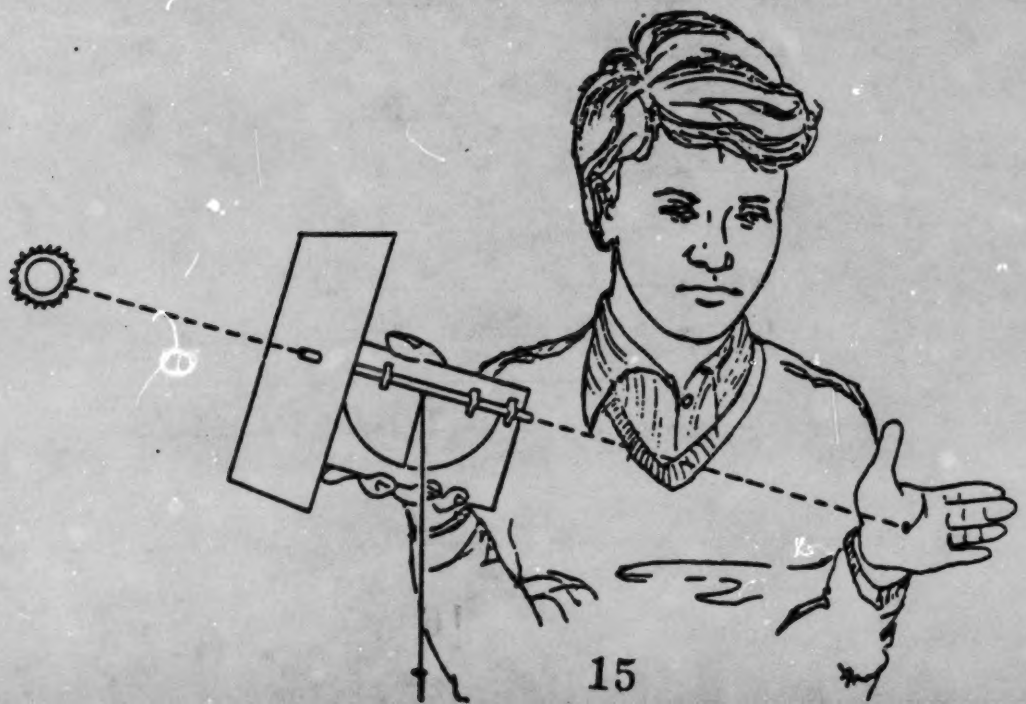
1. Hold your astrolabe so that the string hangs freely down against the protractor.

2. Sight the star or object through the straw. Looking at a star through the straw may take a little practice and patience at first. You may hold your astrolabe close to your eye or at arms length when sighting a star.



3. While you have the object sighted in the straw, press the string against the protractor and read off the number of degrees. The number of degrees equals the altitude of the star.

CAUTION: DO NOT OBSERVE THE SUN THROUGH THE STRAW. To find the altitude of the sun, first place a piece of dark stiff paper around the front end of the straw. Then point the straw at the sun until a bright spot of light appears on your hand. See diagram below. When the bright spot appears, read the number of degrees under the string at that time.



ACTIVITIES USING YOUR ASTROLABE:

1. Measure the altitude of any star. Repeat the measurement with the same star at least three times in a row. Record your answers below.

Star name _____ Altitude _____

_____

_____

_____

If you got different answers each time, why do you think that happened?

_____

_____

2. For this activity use the North Star (Polaris) and one other bright star which you can identify in the current night sky. At the same time each night, stand in the same place and use your astrolable to measure the height of Polaris and the other star. Make these observations for two weeks on every clear night. Record your observations below.

Date	Time	Altitude of Polaris	Altitude of _____ (star name)

Compare your observations for the two stars above. Describe any changes in altitude you observe.

_____

_____

_____

3. Check a calendar for the date of the next NEW MOON. Begin this activity about 4 days after the new moon. On every clear night for the next 10 nights, at the same time (7 p.m. for example) and standing in the same place, measure the altitude of the moon. Record your observations below.

Date	Time	Altitude of the moon

Is the altitude of the moon changing? _____ If YES, is it getting higher or lower each night? _____. How much does it change from one night to the next? _____

_____

4. Check the calendar for the date of the next FULL MOON. On that night measure the altitude of the full moon every hour for two or three hours beginning about 7 p.m. Record your observations below.

Date	Time	Altitude of the moon

How much does the altitude change in one hour? _____

5. Read the CAUTION about observing the sun (bottom of page INSTRUCTIONS FOR USING YOUR ASTROLABE). On a sunny day, measure the altitude of the sun once each hour beginning about 9 or 10 a.m. and continuing until 3 or 4 p.m. Record your observations below.

Date	Time	Altitude of the sun
_____	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____

What was the highest altitude of the sun that you observed? _____

6. Repeat the sun altitude observations in one month. Record your observations below. Try to observe about the same times as activity 5 above.

Date	Time	Altitude of the sun
_____	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____

What was the highest altitude of the sun that you observed? _____

Compare the observations in activities 5 and 6. How are they different? How are they alike?

_____

_____

_____

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Science Museum of Virginia.

RETROGRADE MOTION OF MARS

OBJECTIVE: After completing this activity, the student should be able to describe the path of Mars through the background starfield from May through December 1971.

MATERIALS: Pencil, star chart and table (included)

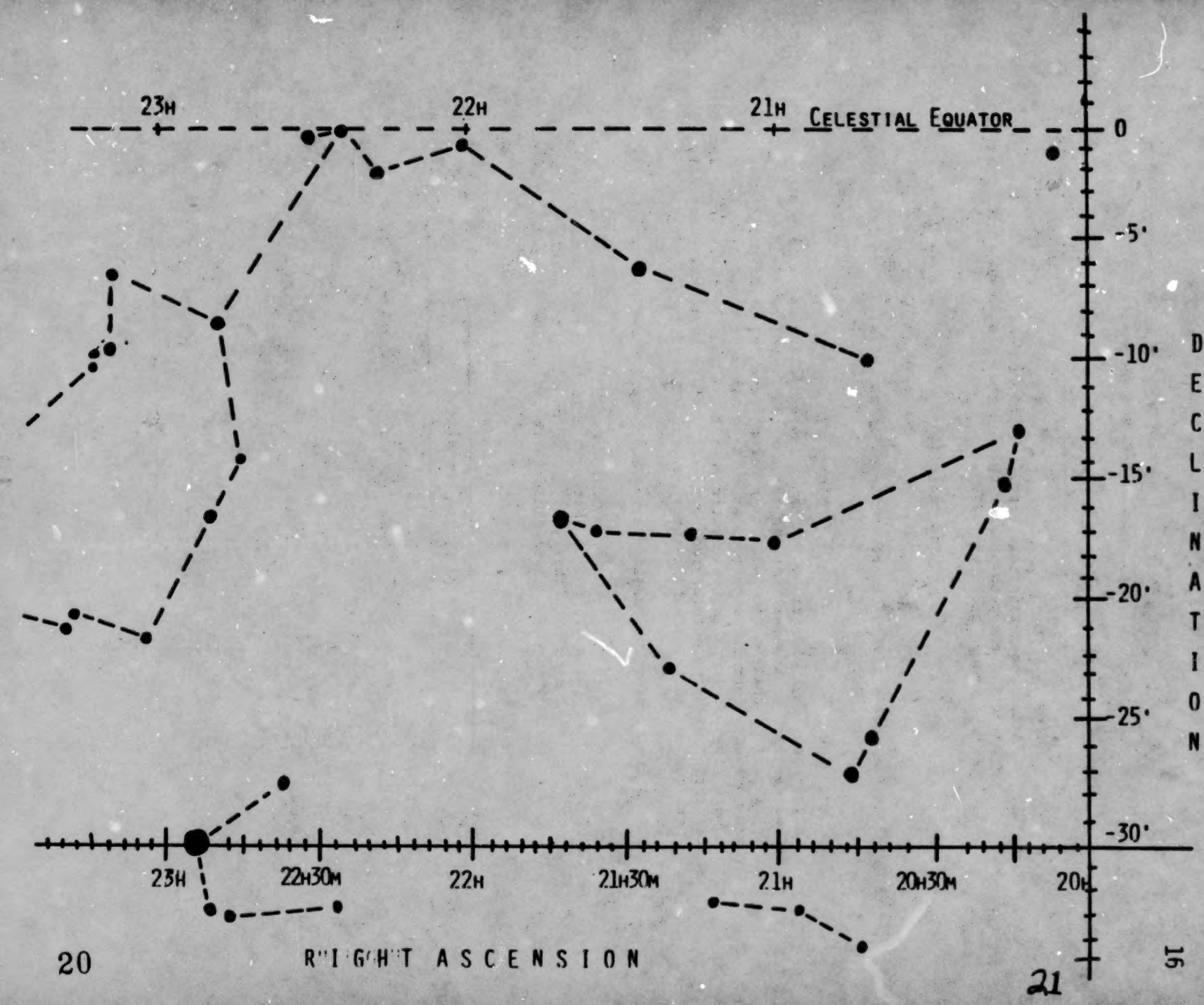
OTHER REQUIREMENTS: This activity can be completed in the classroom in less than one hour.

In the early days of astronomy, planets were distinguished from stars by their "wanderings" or apparent motions through the fixed starfield. One puzzling aspect of their motion was the apparent reversal of direction and backward movement (retrograde motion) at certain times of the year. Elaborate models were proposed to explain the retrograde loops made by the planets, and dissatisfaction with the accuracy and complexity of these models eventually led Copernicus to his heliocentric theory of the Solar System.

This activity demonstrates the retrograde loop followed by Mars during 1971.

PROCEDURE: Plot the positions for Mars given in the table on the star map. Label each position ① ② ③... and connect the dots. Draw arrows on the path to indicate the direction of travel.

	DATE	RIGHT ASCENSION	DECLINATION
①	May 1	$20^h\ 04^m$	-22°
②	June 1	$21^h\ 05^m$	-20°
③	July 1	$21^h\ 41^m$	-19°
④	July 13	$21^h\ 45^m$	-19°
⑤	Aug. 1	$21^h\ 36^m$	-21°
⑥	Sept. 1	$21^h\ 07^m$	-23°
⑦	Sept. 11	$21^h\ 04^m$	-23°
⑧	Oct. 1	$21^h\ 15^m$	-21°
⑨	Oct. 15	$21^h\ 32^m$	-18°
⑩	Nov. 1	$22^h\ 01^m$	-15°
⑪	Nov. 15	$22^h\ 28^m$	-11°
⑫	Dec. 1	$23^h\ 02^m$	-7°


23H
22H
21H
CELESTIAL EQUATOR
0
-5°
-10°
-15°
-20°
-25°
-30°
DECLINATION
23H
22H30M
22H
21H30M
21H
20H30M
20H
RIGHT ASCENSION
20
21
16

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MEASURING THE SUN'S DIAMETER

OBJECTIVES: After completing this activity, the student, should be able to:
1. state the diameter of the Sun in kilometers, and
2. demonstrate one method for measuring the Sun's diameter.

MATERIALS: Meter stick, two 3 x 5 index cards, pencil, pin, tape.

OTHER REQUIREMENTS: The Sun must be clearly visible to do this activity, which can be completed within one hour.

The Sun is 150 million kilometers away from the Earth, yet it is possible to measure its diameter. The Sun is much closer to the Earth than any other star, and it is the only star whose surface can be studied in detail. Our knowledge about the Sun's size, surface and atmosphere permits us to better understand the physical nature of the billions of other stars in our Milky Way and other galaxies.

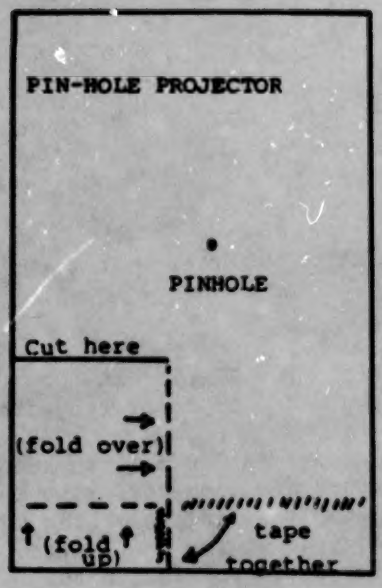
There are several techniques for determining the Sun's diameter, and one method is described in this activity. When doing activities that involve study of the Sun, remember to <u>never look directly at the Sun</u>, since that may cause eye damage.

PROCEDURE: One index card will be used as a pin-hole projector to project an image of the Sun onto the other card. By measuring the size of the Sun's image and the distance between the cards, the diameter of the Sun can be computed.

1. Draw four equally spaced, parallel lines (with a separation of precisely 2mm) near one edge of an index card. Use a sharp pencil. These lines will serve as a scale to measure the size of the Sun's image.

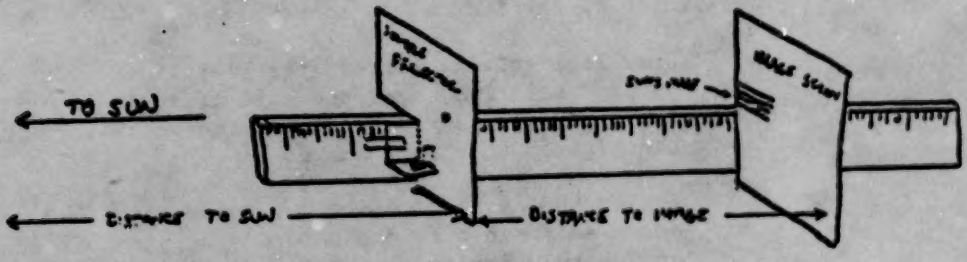
2. Follow the pattern shown to prepare the other index card to serve as a pin-hole projector. The pin-hole should be neat and sharply defined, with no ragged edges. The tab should be cut and folded as shown, so the card can be mounted perpendicular to the meter stick. Tape this card near one end of the stick.

3 x 5 index card



3 x 5 index card

3. The meter stick with pin-hole projector attached should be pointed towards the Sun. The other card should be held behind the pin-hole to receive the Sun's image. It is safe to look at the sun's image but DO NOT look through pin-hole at the sun.



4. Adjust the distance between the two cards until the image of the Sun is exactly 2 mm in diameter (it will fill the space between two adjacent parallel lines).

5. The position of the index cards should now be recorded and the distance between them determined.

6. Using the formulae below, compute the Sun's diameter.

$$\frac{\text{Diameter of Sun}}{\text{Distance of Sun}} = \frac{\text{Diameter of Image}}{\text{Distance of Image}}$$

$$\text{Diameter of Sun (km.)} = \frac{\text{Diameter of Image (mm.)} \times \text{Distance to Sun (k}}{\text{Distance to Image (mm.)}}$$

7. Adjust the distance between the cards until the Sun's image is exactly 4 mm. (then 6mm.). Repeat steps 5 and 6 to again determine the Sun's diameter. Record your answers in the table.

Diameter of Image	Distance to Image	Distance to Sun	Diameter of Sun
2 mm.	mm.	1.5×10^8 km.	km.
4 mm.	mm.	1.5×10^8 km.	km.
6 mm.	mm.	1.5×10^8 km.	km.

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FINDING THE SUN'S ALTITUDE

OBJECTIVES: After completing this activity, the student should be able to:

1. measure the Sun's altitude,
2. describe how the Sun's altitude changes throughout a day, and
3. describe how the noontime altitude of the Sun changes throughout the year.

MATERIALS: 8-1/2 x 11 sheet of cardboard, scissors, glue.

OTHER REQUIREMENTS: This activity requires observations of the shadow cast by the Sun for various times during the day, and for objective (3), for various days throughout a year.

The Earth's daily rotation, its annual revolution (motion along its orbit), and the tilt of its axis all combine to change the altitude of the Sun above the horizon. The change in the Sun's altitude can be measured with a simple, shadow-casting device. These measurements can then be used to discover the interesting patterns in the Sun's apparent path through the sky.

PROCEDURE: Follow the instructions for making a device to measure the Sun's altitude. Glue the device to cardboard sheet for greater stability. Record the altitude of the Sun at 1 hour intervals throughout one day. Record the noon altitude of the Sun at weekly intervals throughout one year.

SHADOW CASTER

CUT NOTCH

FOLD UP ALONG DASHED LINES

ALONG DASHED LINES FOLD UP

SUN LINE

75°
65°
55°
45°
35°
25°
15°

80°
70°
60°
50°
40°
30°
20°
10°

FINDING the SUN'S ALTITUDE

NEVER LOOK DIRECTLY AT THE SUN

SHADOW SCALE

SUN LINE — POINT THE ARROWS TOWARD THE SUN — SUN LINE

1. CUT ALONG TOP EDGE AS INDICATED CUT NOTCH IN TOP EDGE.
2. FOLD ALONG DASHED LINE SO TOP EDGE POINTS STRAIGHT UP.
3. PLACE THE SHADOW SCALE IN FRONT OF YOU WITH THE SUN LINE POINTED TOWARD THE SUN.
4. TURN THE SHADOW SCALE SO THE NOTCH'S SHADOW FALLS DIRECTLY ON THE SUN LINE BE SURE THE SHADOW CASTER POINTS STRAIGHT UP.
5. THE SHADOW OF THE TOP EDGE OF THE SHADOW CASTER WILL FALL ON THE SCALE, MARKING THE SUN'S ALTITUDE.

FINDING THE SUN'S AZIMUTH

OBJECTIVES: After completing this activity, the student should be able to:

1. define azimuth,
2. measure the Sun's azimuth,
3. describe how the Sun's azimuth changes throughout a day.

MATERIALS: 8-1/2 x 11 sheet of cardboard, glue, nail (2 to 5 cm. long)

OTHER REQUIREMENTS: This activity requires observations of the shadow cast by the Sun for various times during the day.

Azimuth is one coordinate used by surveyors, navigators and astronomers for locating objects. Azimuth is measured around the horizon, beginning at the North point (0^{o}) and increasing towards the East (90^{o}). The azimuth of an object in the South is 180^{o} and towards the West is 270^{o}.

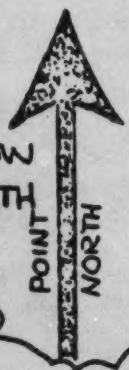
As the Sun moves across the daytime sky, its azimuth steadily changes. Recording these changing azimuth directions helps understand the apparent motions of the Sun.

PROCEDURE: Follow the instructions for finding the Sun's azimuth. Record the value of the Sun's azimuth at 1 hour intervals throughout the day.

INSTRUCTIONS

1. FIX THIS PAGE, USING TAPE OR STRAIGHT PINS TO A PIECE OF CARDBOARD

2. POINT THE LARGE ARROW TOWARD GEOGRAPHIC NORTH (NOON SHADOWS, NORTH STAR, COMPASS - MAY BE USED TO FIND NORTH)

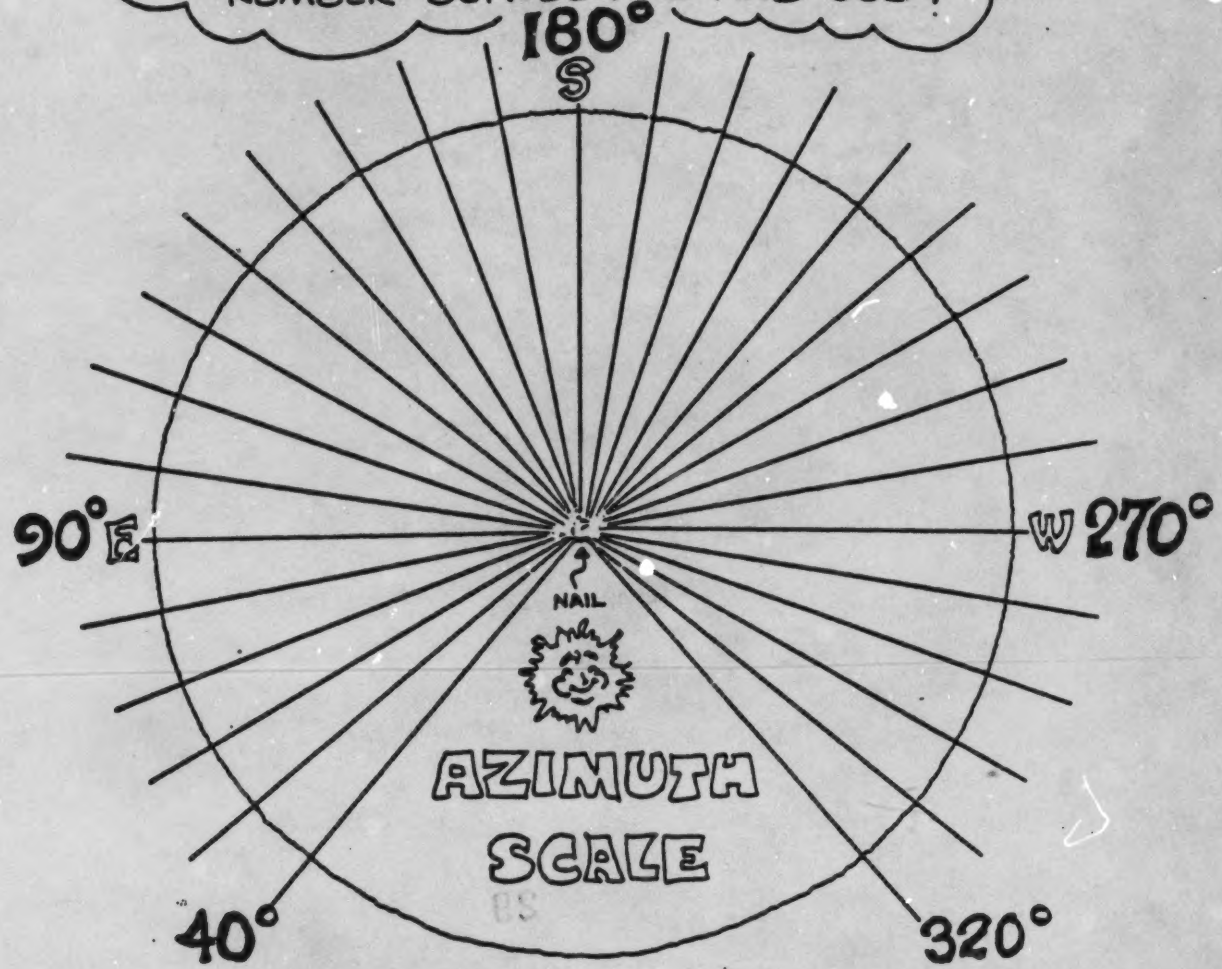


3. PLACE A NAIL (1½" to 2") OR SIMILAR SHADOW CASTING DEVICE AT THE CENTER OF THE AZIMUTH SCALE.

4. READ THE SUN'S AZIMUTH FROM THE SCALE

WHAT IS AZIMUTH?

AZIMUTH IS THE DIRECTION ONE FACES TO SEE AN OBJECT. THE DIRECTION IS EXPRESSED AS A NUMBER BETWEEN 0° AND 360°.



Paul A. Knappenberger, Jr., Ph.D.
Science Museum of Virginia.

OBSERVING SUNSPOTS

OBJECTIVES: After completing this activity, the student should be able to:

1. describe a technique for observing sunspots,
2. recognize and describe the projected image of a sunspot,
3. state the approximate number of sunspots visible during the dates of observation, and
4. compute the rotational period of the Sun.

MATERIALS: Telescope (or binoculars) with tripod, 40 cm. x 40 cm. cardboard square, clipboard, white notebook paper or graph paper, pencil.

OTHER REQUIREMENTS: This activity involves daily observations of the Sun for a period of at least one week. The Sun should never be viewed directly, either through a telescope or with the unaided eye, as it will cause eye damage.

Dark spots occur on the photosphere of the Sun which can be seen by projecting the Sun's image through a telescope onto a viewing screen. These dark areas, called sunspots, are regions of gas that are cooler than the surrounding areas, hence appear darker. Sunspots are associated with magnetic field disturbances on the Sun.

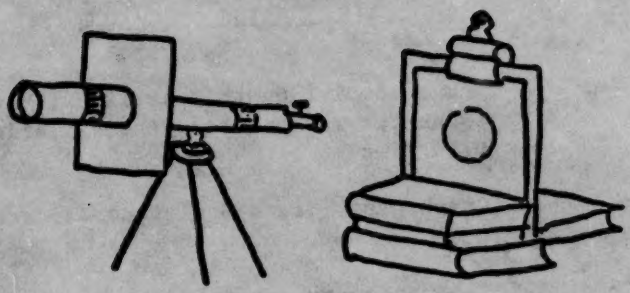
By observing sunspots for a period of one or two weeks, interesting results can be obtained. These spots may change in size, shape and numbers, and will appear to move across the solar disc as the Sun rotates on its axis.

PROCEDURE: When using a telescope to observe the Sun, make certain that only the main telescope lenses are uncovered. This will avoid accidental direct viewing of the Sun through a finderscope. If using binoculars, cover the lenses on one-half of the binoculars.

1. Set telescope on a tripod near a window or at any convenient site for locating the Sun.

2. Cut a hole in the center of the cardboard square so that it fits snugly over the telescope tube. This will serve as a shield to block direct sunlight from reaching the viewing screen.

3. Prop a clipboard into position at a convenient distance behind the telescope eyepiece. (This distance can be several inches or several feet.)



4. Attach plain white paper or graph paper to clipboard to serve as a viewing screen and sketch pad.

5. Focus the Sun's image sharply on the viewing screen by adjusting the position of the telescope eyepiece.

6. Trace the outline of the Sun's image and any sunspots that may be visible. (Do not confuse sunspots with images of dirt spots on the lenses that may be projected on the screen.) Sunspots may show structure, with a dark central region (umbra) surrounded by a grey outer region (penumbra).

7. Record the time and date of observation on the sketch.

8. Repeat the above procedure each day for at least one week.
   a. Use a different sheet of paper on the clipboard each day.
   b. Make sure that the distance from the eyepiece to the viewing screen is the same each day.
   c. Make the observations at nearly the same time each day.
   d. Note any cloudy days.

9. After at least one week, arrange the Sun-image papers in order and note any changes from day to day in the following:
   a. number of sunspots
   b. shape of sunspots
   c. size of sunspots
   d. location of sunspots or sunspot groups

10. Compute the rotation period of the Sun.
    Do all spots appear to move at the same rate?
    Does the sun rotate as a solid body?

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THE SUNSPOT CYCLE

OBJECTIVES: After completing this activity, the student should be able to sketch and describe the variation in sunspot numbers with time.

MATERIALS: Graph paper (rectangular coordinates), pencil, ruler.

OTHER REQUIREMENTS: This activity can be completed in the classroom in less than one hour.

The region of the Sun that radiates most of the light that we see is called the photosphere. The most obvious of the photosphere's many features are the dark, blemish-like sunspots. The Chinese first recorded sunspots as early as 2000 B.C., yet the nature of these spots remained poorly understood until the 1800 and 1900's. Today astronomers are still studying the characteristics of sunspots to develop a better understanding of the physical nature of the Sun.

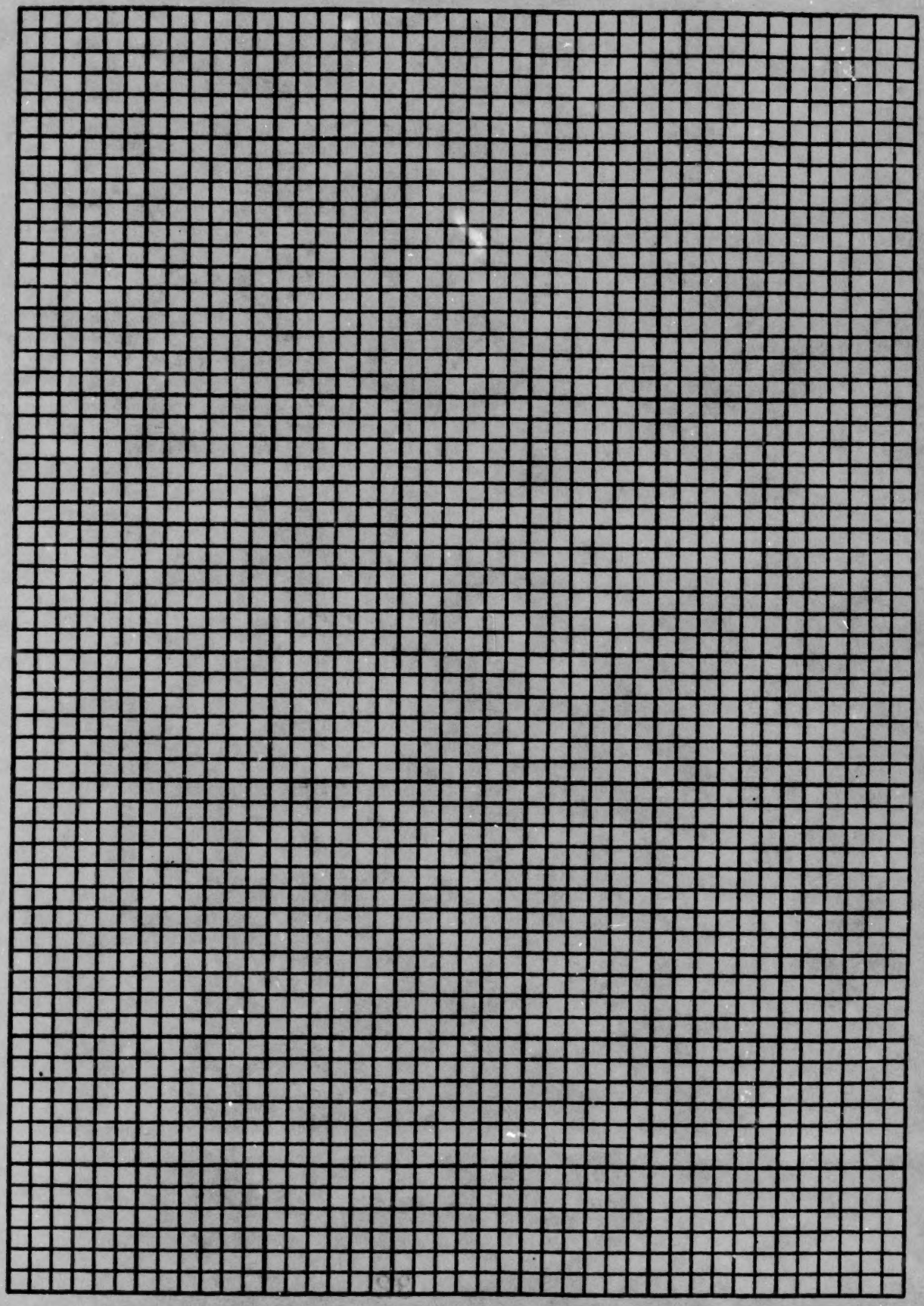
Although single sunspots do occur, more often they are found in pairs. Frequently clusters or groups of sunspots are observed which may cover 50,000 miles of the solar surface, although an individual sunspot is usually only a few hundred miles in diameter. Sunspots last from a few days to several weeks, and have been used to determine the rotational period of the Sun.

The number of sunspots observed in a given year can be plotted against time. This can be somewhat complicated since counts of individual spots are, at best, difficult. A scheme for determining the relative average number of sunspots in a given year has been worked out, and the numbers used are called Zurich numbers (Zurich Observatory). Below is a table of these numbers from 1900 to 1966. The data is provided for you to plot the sunspot cycle.

PROCEDURE: The accompanying table gives the average number of sunspots per year between the years 1900 and 1966. The sunspot number is a measure of the number of sunspot groups per year. Graph the sunspot number versus time on the graph paper. Plot the years on the horizontal axis and the number of spots on the vertical axis.

DATA

Year	Zurich Number	Year	Zurich Number
1900	9.5	1933	5.7
1901	2.7	1934	8.7
1902	5.0	1935	36.1
1903	24.4	1936	79.7
1904	42.0	1937	114.4
1905	63.5	1938	109.6
1906	53.8	1939	88.8
1907	62.0	1940	67.8
1908	48.5	1941	47.5
1909	43.9	1942	30.6
1910	18.6	1943	16.3
1911	5.7	1944	11.0
1912	3.6	1945	33.2
1913	1.4	1946	92.6
1914	9.6	1947	151.5
1915	47.4	1948	136.2
1916	57.1	1949	134.2
1917	103.9	1950	83.9
1918	80.6	1951	69.3
1919	63.6	1952	31.5
1920	37.6	1953	13.9
1921	26.1	1954	4.4
1922	19.2	1955	38.0
1923	5.8	1956	141.7
1924	16.7	1957	189.9
1925	44.4	1958	184.6
1926	63.9	1959	158.8
1927	69.0	1960	112.3
1928	77.8	1961	53.9
1929	65.0	1962	32.6
1930	35.7	1963	27.9
1931	21.2	1964	10.2
1932	11.1	1965	15.1
		1966	47.0
		1967	93.8
		1968	105.9
		1969	105.5
		1970	104.5
		1971	66.6
		1972	68.9
		1973	38.0
		1974	34.5



QUESTIONS

1. What is the average number of years between the maximum and the minimum number of spots?

2. What is the average number of years between the minimum and the maximum number of spots?

3. What is the average number of years between sunspot maxima?

4. What is the average number of years between sunspot minima?

5. What is the average time for the complete cycle?

6. What will be the next year of maximum sunspot activity?

7. What will be the next year of minimum sunspot activity?

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CLASSIFYING STARS

OBJECTIVE: After completing this activity, the student should be able to diagram the relationship between intrinsic brightness and temperature for the stars in our part of the galaxy.

MATERIALS: List of 20 brightest stars, list of 36 closest stars, blank graph for comparing the stars' temperature and brightness (included), pencil.

In studying the physical properties of stars, astronomers classify them according to the different traits which they exhibit. Two traits which are easily compared are the star's intrinsic brightness and the star's temperature. The plot of temperature versus intrinsic brightness, known as the H-R diagram, is of fundamental importance in astronomy. Much of our knowledge of stellar evolution has developed from use of this relationship.

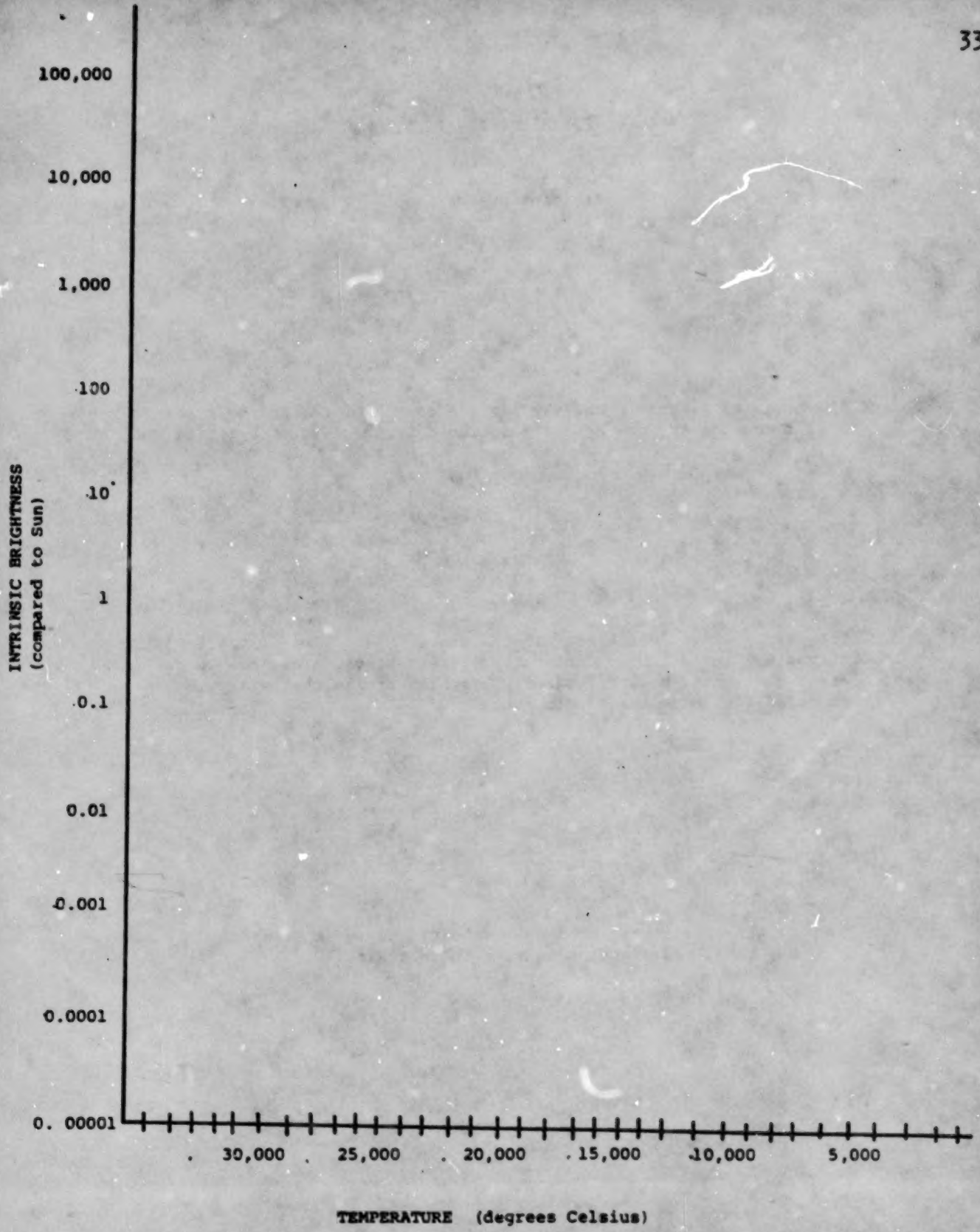
PROCEDURE: To compare stars according to these traits, plot the intrinsic brightness and temperature for each of the stars on the attached lists. Be sure to keep track of which points correspond to the 20 brightest stars and which points correspond to the 36 closest stars.

THE 20 BRIGHTEST STARS IN OUR SKY

Star Name	Intrinsic Brightness (compared to Sun)	Temperature (° Censius)	Mass (compared to Sun)	Distance (light years)
Sirius	27	11,000	2.4	8
Canopus	1,700	8,000		90
α Centauri	1.7	6,000	1.0	4
Arcturus	115	5,100		33
Vega	65	12,000	2.6	24
Capella	190	6,200		42
Rigel	50,000	16,000		750
Procyon	8.3	7,000	1.4	10
Betelgeuse	15,000	2,800		450
Achernar	250	18,000	5.0	60
β Centauri	4,300	21,000		270
Altair	13	8,200	1.9	15
α Crucis	4,000	21,000		360
Aldebaran	120	4,000		48
Spica	2,700	21,000	15.0	240
Antares	6,300	3,000		360
Pollux	70	5,700		36
Fomalhaut	15	9,400	2,1	21
Deneb	57,000	11,000		1,290
β Crucis	6,900	2,400		450

THE 36 NEAREST STARS TO THE SUN

Star Name	Intrinsic Brightness (compared to Sun)	Temperature (° Celsius)	Mass (Compared to Sun)	Distance (light years)
α Centauri	1.7	6,000	1.0	4
Barnard's star	0.0005	2,200	.35	5.4
Wolf 359	0.00002	2,000	.3	7
Lalande 21185	0.006	2,800	.45	7.5
Sirius	27	11,000	2.4	8.1
Luyten 726	0.00007	2,100	.32	8.1
Ross 154	0.0005	2,300	.37	9
Ross 248	0.001	2,100	.32	9.4
ε Eridani	0.4	5,000	.67	9.9
Ross 128	0.0004	2,200	.35	10.1
Luyten 789	0.0001	2,100	.32	10.1
61 Cygni	0.1	4,000	.6	10.2
Procyon	8.3	7,000	1.4	10.4
ε Indi	0.2	4,000	.6	10.4
Σ 2398	0.004	2,400	.4	10.8
BD+43°	0.008	2,700	.42	10.8
τ Ceti	0.5	5,500	.8	10.9
CD-36°	0.01	2,800	.45	11.0
DD+5°	0.002	2,400	.4	11.1
CD-39°	0.03	3,200	.5	11.7
Kruger 60	0.002	2,600	.42	11.8
Ross 614	0.0005	2,300	.37	12.0
BD-12°	0.002	2,300	.37	12.3
v. Maanen's star (wd)	0.0002	8.000		12.6
Wolf 424	0.0002	2,100	.32	13.3
BD+50°	0.05	3,200	.5	13.5
CD-37°	0.07	2,600	.42	13.7
CD-46°	0.03	2,400	.4	14.1
BD+20°	0.04	2,400	.4	14.2
CD-44°	0.0008	2,200	.37	14.3
CD-49°	0.004	2,600	.42	14.3
AD 17415	0.005	2,600	.42	14.4
Ross 780	0.002	2,200	.37	14.4
Lalande 253,72	0.007	2,800	.45	14.5
CC 658 (wd)	0.001	10,000		14.7
40 Eridan9	0.4	5,200	.7	15.0


100,000
10,000
1,000
100
10
1
0.1
0.01
0.001
0.0001
0. 00001
INTRINSIC BRIGHTNESS
(compared to Sun)
30,000
25,000
20,000
15,000
10,000
5,000
TEMPERATURE (degrees Celsius)

FURTHER ACTIVITIES

1. If you look at the graph as a whole, it divides up into 3 distinct groups. How might you go about dividing up the graph? What names would you give to each group of stars?

2. The brightest stars in the sky include only 3 of the nearby stars. Why aren't more of the nearby stars included in the list of brightest stars?

3. The nearby stars (which are all the stars in a volume of space 15 light years in radius) include only 3 of the brightest stars. What can we conclude about the number of intrinsically bright stars in the galaxy in general compared to the number of dim stars?

4. Compare the star's mass to its luminosity and to its temperature. Can you find any basic relationship between these traits?

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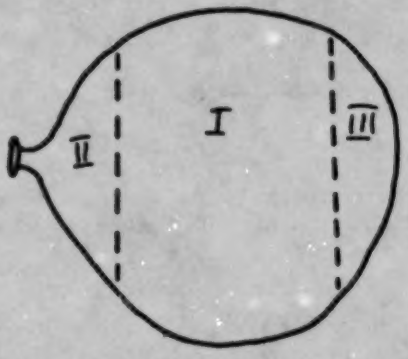
EXPANDING UNIVERSE MODEL

OBJECTIVES: After completing this activity, the student should be able to:
1. demonstrate with a model that the universe appears to expand regardless of the reference point from which it is viewed,
2. obtain a velocity distance relationship analogous to Hubble's Law.

MATERIALS: String (two pieces, each 40 cm. long), a medium-sized balloon (spherical shape is best), felt tip marking pen (different color from balloon), ruler, graph paper.

OTHER REQUIREMENTS: This activity can be completed in the classroom in one hour.

Nearly all of the galaxies show redshifts in their spectra, which indicate that the Universe is expanding. The farther a galaxy is away from us, the faster it appears to be receding. A simple model involving a balloon can be used to demonstrate this effect and to derive a distance-velocity relationship similar to Hubble's Law for the expansion of the Universe.



1. Inflate the balloon and use a felt tip pen to mark:
   A. our galaxy: (MW)
   B. five other galaxies: (a) (b) (c) (d) and (e)
   C. any arbitrary point: (P)

   Mark only in region 1 as shown in the diagram, since regions II and III do not expand at a steady rate.

2. On one piece of string mark off lengths of 15 and 30 cm.

3. Make a centimeter ruler out of a second piece of string.

4. Inflate the universe so that its circumference in region 1 is 15 cm and complete the first part of Table 1. Then inflate the universe so that the circumference is 30cm and complete the second part of Table 1. Use centimeter ruler string to measure arc-distances on balloon's surface.

TABLE 1

Point	Distance from (MW) to		Distance from (P) to	
	ARC AT C = 15	ARC AT C = 30	ARC AT C = 15	ARC AT C = 30
(a)				
(b)				
(c)				
(d)				
(e)				
(MW)	———	———		

5. Use Figure 1 to convert ARC distances to chord distance by laying off the arcs with the string and measuring the corresponding chord with a ruler. Enter results in Table 11.

TABLE 11

POINT	Distance from (MW) to		Distance from (P) to	
	Chord AT C = 15	Chord AT C = 30	Chord AT C = 15	Chord AT C = 30
(a)				
(b)				
(c)				
(d)				
(e)				
(MW)	———	———		

6. Use Table 11 to calculate:

   a. the velocity of each point by using

   $$V = \frac{\Delta D}{\Delta T} = (\text{Chord at } 30 - \text{Chord at } 15)/1$$

   Where ΔT = 1 unit of time

   b. The average distance of each point = $\overline{D}$, where

   $\overline{D}$ = (Chord at 30 + Chord at 15)/2

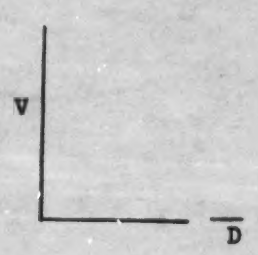
7. Enter the results in Table 111.

TABLE 111

Point	As seen from MW		As seen from P	
	V	$\overline{D}$	V	$\overline{D}$
a				
b				
c				
d				
e				
MW				

8. Use graph paper to

   plot V vs. $\overline{D}$



and indicate the points that are viewed from MW by enclosing them in a circle (⊙) and the points that are viewed from P by enclosing them in a triangle (△).

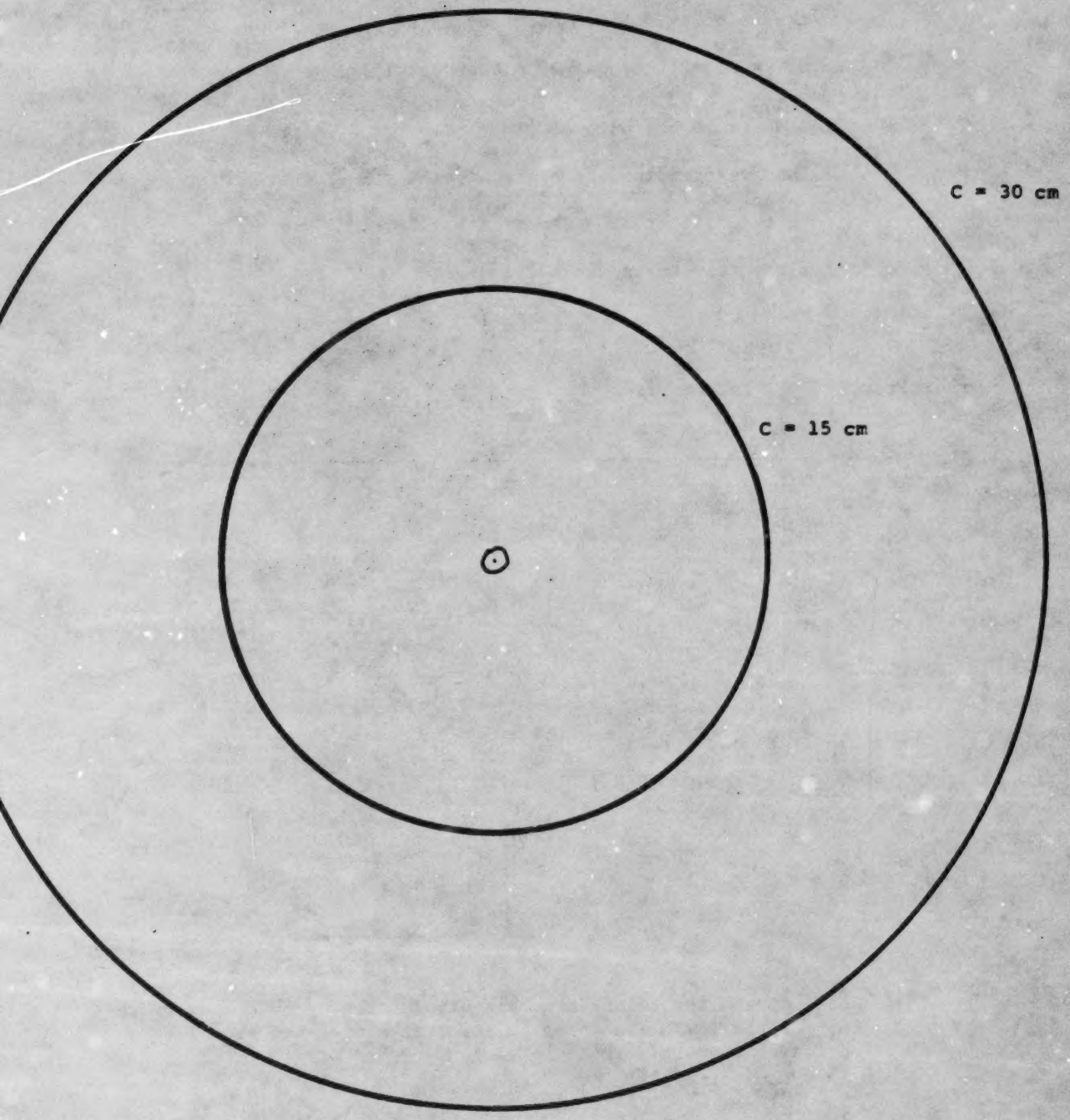


FIGURE 1

Use to convert arc-distance to chord distance for Table II

SAMPLE RESULTS

TABLE 1

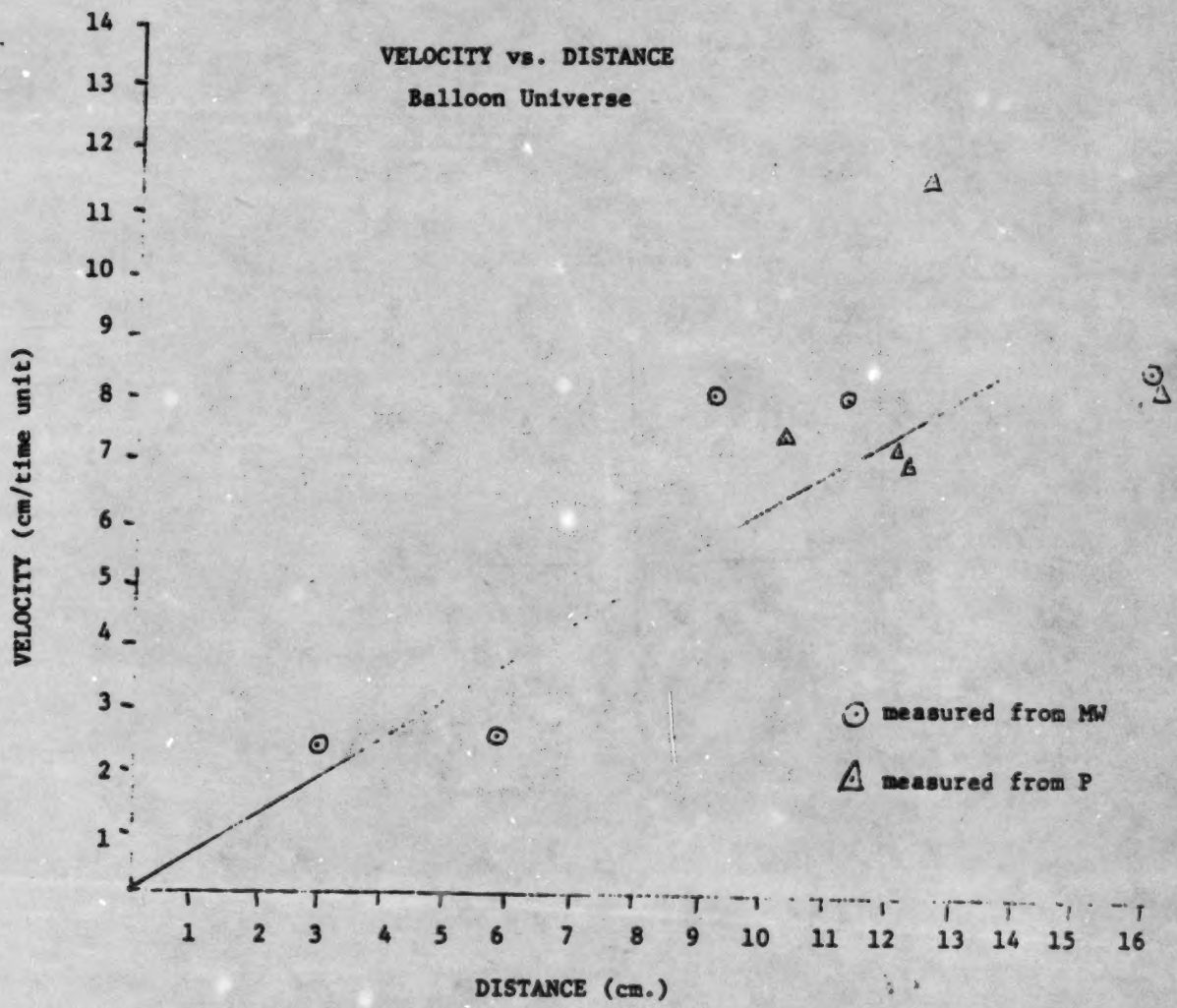
Point	From MW to		From P to	
	ARC AT C = 15	ARC AT C = 30	ARC AT C = 15	ARC AT C = 30
a	1.7 cm	4.3	7.4	16.5
b	8.0	18.0	13.3	30.8
c	5.5	15.0	7.5	25.2
d	12.6	31.3	10.0	18.8
e	4.7	8.0	10.4	18.7
MW	———	———	5.7	12.5

TABLE 11

Point	From MW to		From P to	
	Chord AT C = 15	Chord AT C = 30	Chord AT C = 15	Chord AT C = 30
a	1.6	4.1	6.5	14.2
b	7.1	15.4	11.6	19.9
c	5.1	13.3	6.6	18.7
d	11.4	20.0	8.3	15.8
e	4.4	7.1	8.6	15.7
MW	———	———	5.2	11.3

TABLE 111

Point	As seen from MW		As seen from P	
	V	$\overline{D}$	V	$\overline{D}$
a	2.5	2.9	7.7	10.4
b	8.3	11.3	8.3	15.8
c	8.2	9.2	12.1	12.7
d	8.6	15.7	7.5	12.1
e	2.7	5.8	7.1	12.2
MW			6.1	8.3



MOON PHASE MODEL

As the moon and earth orbit the sun the moon appears to change phase.

PROBLEM: To draw a scaled model of the moon phases.

MATERIALS: 120 cm. piece of paper, string, colored pencils, protractor.

PROCEDURE:

1. Using the scale 1 cm. = 1,500,000 km, use your string to draw a part of the earth's orbit. Use one corner of your paper to represent the sun.
2. Use your protractor to divide this orbit into three 30° sections.
3. Further divide each 30° section into four more sections of 7.5°.
4. Draw in the earth at each of these twelve locations:
5. Now find out the position of the moon relative to the earth and sun for a new moon phase, first quarter phase, full moon phase and last quarter phase.
6. Place the moon correctly in each of the twelve locations to show this sequence of phases.

QUESTIONS:

1. Does the moon orbit the earth, the sun, or both? Explain.

_____

_____

_____

2. What length of time is necessary for the earth and moon to travel one of the 30° segments. _____

_____

_____

3. Is the sun shining on the moon when we see the new moon phase? Explain.

_____

_____

_____

4. Define:

a) waxing moon _____

_____

b) waning moon _____

_____

c) sidereal month _____

_____

d) synodic month _____

_____

AUDIO-VISUAL AIDS FOR ASTRONOMY

We present here a list of dependable suppliers for 35 mm slides, overhead transparencies, audio tapes, films, posters, charts and related items for use in teaching astronomy at all levels from the public school to university. Other sources for such materials do exist, but those listed here should be able to satisfy all your requirements in this area. In general, catalogues are available free of charge when requested on school letterhead.

Most planetaria have retail counters from which this type of material may be obtained as well as books and telescopes.

Some of the suppliers listed here, and others, occasionally advertise new items and special offers in popular magazines such as Sky and Telescope, New Scientist, or Astronomy.

Lick Observatory
Photographic Department
University of California
Santa Cruz, California 95060

- 35 mm slides and prints of this observatory and of celestial objects photographed with its telescopes. Many are of historical interest.

Caltech Bookstore
1201 E. California Blvd.
Pasadena, California 91109

- Slides and prints of the Palomar and Mt. Wilson Observatories, and of celestial objects photographed with their telescopes.

MMI Corporation
2950 Wyman Parkway
Baltimore, Maryland 21211

- Probably the most complete supplier of slides, charts, tapes, booklets and other aids including globes, and planetaria (orreries). NASA slides.

Tersch Enterprises
P.O. Box 1059
Colorado Springs, Colorado 80901

- Wide range of 35 mm slides of celestial objects, astronomical concepts, and NASA missions.

Royal Astronomical Society
Burlington House
Piccadilly
London W1V 0NL

- Slides and prints from sources in the eastern as well as western hemispheres. Many of historical interest.

Astro Cards
P.O. Box 35
Natrona Heights, Pa. 15065

- Slide sets, finder charts, and cassette tapes.

Hansen Planetarium
15 South State Street
Salt Lake City, Utah 84111

- Slides, posters and charts.

Astronomical Society of the Pacific
1290 - 24th Avenue
San Francisco, California 94122

- A limited range of slides, prints and posters.

National Geographic Society
16th and M Streets N.W.
Washington, D.C. 20036

Request a copy of the map catalogue which includes several charts of the Moon, sky and Mars.

U.S. Government Printing Office
Washington, D.C. 20402

Request copies of current catalogues which list available NASA-produced and astronomy-related materials. A number of high-quality but very inexpensive posters and charts related to manned and unmanned space exploration are available.

NASA Educational Programs Division
Office of Public Affairs
Code FE
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or

Educational Programs Officer
Public Affairs Office
NASA, Ames Research Center
Moffett Field, California 94035

Good sources of pamphlets, brochures, posters, etc. and information relevant to the teaching of astronomy and space-related topics.

Astro Optics
Dept. D
1979 Buffalo Road, Rte 1
Darien Center, N.Y. 14040

Astro-Murals
P.O. Box 7563-T
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- Brochures, news releases and photographs from and about recent NASA space missions.

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The British Broadcasting Corp.
135 Maitland Street
Toronto, Ontario M4Y 1E5

- Catalogue available.

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Department of Extension
University of Alberta
Edmonton, Alberta T6G 2J1

- Repository for all NASA films. Others also available on a rental basis. Catalogue available.

National Science Film Library
Canadian Film Institute
1762 Carling Avenue
Ottawa, Ontario K2A 2H7

- Depository for all NASA films. Catalogue available.

Film List: NASA
Code FAD
Washington, D.C. 20546

- Request list of NASA films for sale. (To rent NASA films apply to previous two sources.)

Modern Film Rentals
1875 Leslie Street
Don Mills, Ontario M3B 2M6

- Catalogue available.

Recommended Films:

Several hundred films on astronomy are now available. Many, though out of date and of historical interest, still convey a sense of wonder and excitement. We present a very small selection of some of the better films available from one or other of the suppliers listed above.

"UNIVERSE" (B&W, 28m, NFB). A classic film which is slightly out of date in places. An excellent introduction to general astronomy.

"THE CRAB NEBULA" (Colour, 50m, BBC). An outstanding film which shows how much of the development of modern astrophysics is reflected in the study of this one object and its pulsar. Illustrates the methodology of scientific research.

"THE BLACK HOLES OF GRAVITY" (Colour, 50m, BBC). Outstanding description of the historical development of Man's concepts of gravity and the structure of space, including the development of General Relativity and the discovery (?) of the Black Hole.

"APOLLO 17: ON THE SHOULDERS OF GIANTS" (Colour, 28m, NASA). The last of the Apollo mission films. The Apollo 15, 16 and 17 missions employed the rover vehicle which resulted in extensive photographic coverage of lunar surface features. The earlier mission films are of more historical interest.

"CHALLENGE AND PROMISE" (Colour, 25m, NASA). A fascinating description of some of the technological and medical benefits to society of the space program.

"UNIVERSE II" (Colour, 25m, NASA). A general introduction to astronomy and the evolution of the Universe from the big bang to its final demise.

"JUPITER ODYSSEY" (Colour, 29m, NASA). An excellent record of the development, launch and successful rendezvous with Jupiter of the Pioneer 10 probe. Discusses the significance of the project. Includes photos taken during the mission, and interviews with the people involved.

"TO THE EDGE OF THE UNIVERSE" (Colour, 23m, NFB). Shows the construction of the Algonquin Park radio telescope and describes the research carried out with it. Describes the World's first successful long-baseline interferometric observations made with this telescope in 1967 by Canadian scientists.

"HORIZON: THE PLANETS" (Colour, 50m, BBC). Leading planetologists interpret the findings from spacecraft to Mars, Venus, Mercury and Jupiter in terms of the formation of the planets and of the Solar System. An excellent introduction to the major bodies of the Solar System.

"19 MINUTES TO EARTH" (Colour, 13m, NASA). Describes the results of the Viking missions to Mars.

"MERCURY: EXPLORATION OF A PLANET" (Colour, 24m, NASA). Describes the Mariner 10 mission to Venus and Mercury in 1974. Analysis of the photographs leads to an evolutionary history for Mercury.

FILM LOOPS

Film loops on astronomical topics may be purchased and/or rented from the following:

AAPT Film Repository
American Association of Physics Teachers
Executive Office
Publications Department, Drawer AW
Stony Brook, N.Y. 11790

Approximately two dozen titles are available at member and non-member rates. Most are in colour and approximately 4 minutes in length. Subjects include the effects of weightlessness, lunar gravity, Apollo missions, Mariner missions to Mars, etc. Write for a complete list.

Arbor Scientific Limited
P.O. Box 113
Port Credit, Ontario

Request a copy of the Wards Catalogue which lists several 3 or 4 minute film loops. In particular, a series on orbital motions in a gravitational and other force fields is recommended.

Houghton Mifflin Co., Ltd.
Pennington-Hopewell Road
Hopewell, N.J. 08525

Explorations in Space and Time is a series of eight 16 mm films or twelve 8 mm computer-generated films created by M. L. Meeks, M.I.T. Useful as supplements to regular lectures or for independent study by students. Films illustrate various dynamical laws and phenomena in astronomy such as Keplerian motion, Newton's Laws of motion, motions in a binary star system and stellar proper motions. May be purchased or rented.

AUDIO TAPES

One hour and half hour audio tapes (reel and cassette) of various CBC radio broadcasts which are available for purchase are listed in Audio Tape Catalogue and the Supplements which may be obtained on request by writing to

CBC Learning Systems
Box 500, Station A
Toronto, Ontario
M5W 1E6

Topics available include relativity, cosmology, quasars, moon colonies, interplanetary space, manned and unmanned space probes, etc. Scientists interviewed include Tom Gold, Hermann Bondi, Isaac Asimov, John Percy, Tom Bolton, and astronaut Wally Schirra.

Additional tapes are listed in Ward's Catalogue available from

Arbor Scientific Ltd.
P.O. Box 113
Port Credit, Ontario

Douglas P. Hube

Star Charts

Choosing a star chart which is appropriate and useful for a particular observing session may not always be as easy as one might expect. For constellations, a star chart is needed which does not give too much detail. On the other hand, if you are looking for some obscure Messier objects, then you may need a more detailed star chart. Listed below, in rough order of increasing detail, are the star charts with which I am familiar, and which I have found useful for teaching.

1. "Star Maps for Beginners" by I. M Levitt and Roy K. Marshall (Simon and Schuster, 1973). About $3.

   For constellation study, this booklet is just about unbeatable. The sky is shown divided into four quadrants, with the sky for each month as one faces south, east, north, or west (drawn for 40° latitude). The resulting star maps are far easier to use than those maps which are drawn in the usual circular format (e.g. in Sky & Telescope). Just enough detail has been provided, along with a few connecting lines, so that constellations are easily located. A short write-up accompanies each monthly map. The presentation here is particularly good for locating unknown constellations and for constellation observing sessions in introductory courses.

2. "Whitney's Star Finder" by Charles A. Whitney (Alfred A. Knopf Press, 1974). $6.95

   In the form of a paperback book, with a "Locator Wheel" (a plastic overlay disk) tucked in the back cover. The book contains useful hints and instructions for using the Star Finder, which will indicate locations of prominent stars for different dates and different times of the night. A good idea, but I find the constellations rather cramped on the little card; not as good in my opion for teaching a course as the above entry, but probably useful for the absolute neophyte.

3. "Norton's Star Atlas" by A. P. Norton (Sky Publishing Corp., 1975). $12.50

   An old standard and real classic reference for amateur astronomers; detailed star charts show stars as faint as 6th magnitude, as well as

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nebulae, Messier objects, etc. In addition, the book contains pages of information useful to the stargazer. Recently revised and updated. One of the best star charts available for general purpose.

4. "Astro-Cards (Finder Charts)" by George Kepple (156 Beale Road, Sarver, PA 16055 U.S.A.) $6.95

   For observing the spectacular nebulae among the Messier objects or the NGC objects, one of the best references is these finder charts on index cards. Each index card contains a large scale map, showing the objects location within its constellation. A A detailed finder chart locates the object more closely. The index cards can be shuffled to provide only those objects for one night's observing, avoiding unnecessary moisture for the rest. Handy and very useful.

5. "The Becvar Atlases" by Antonin Becvar (Sky Publishing Corp.)

   A very respected set of atlases, very useful for detailed work. The Atlas of the Heavens ($14) shows more than 35,000 celestial objects; about 13 x 16 inches in size, with plastic coordinate overlay grid. A Field Edition is available ($8). Yet a more detailed series is available, the Atlases Borealis, Eclipticalis, and Australis. The faint limit for stars is about 9 magnitude, and 80 maps show the entire sky. Six colors are used to denote stellar temperature and other information. Each of these three is about 18 x 24 inches. $70 for the set.

RECOMMENDATIONS

I recommend that a copy of "Star Maps for Beginners" be purchased first, to learn one's way around the sky. For more detail, I recommend "Norton's Star Atlas" as an all around reference for casual observing.

Dr. David L. DuPuy

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Astronomical Telescopes For Teaching

While an introductory astronomy course can be taught without benefit of a telescope, the course will attract more students and be a lot more exciting if a telescope is used to advantage. The purpose of this section is to discuss our experiences (and biases) regarding small telescopes for teaching. We will restrict this to small, portable telescopes, and we assume that the telescopes will be used for visual observations or photography. A permanently mounted steel pier is recommended, instead of the usual wooden tripod; in addition to being virtually vibration-free, the polar axis of the telescope will be on the north pole every time (that's a real help if you're searching for new objects). Set-up time is reduced and your observing session will be off to a good start.

A good source for star charts, star finders, and books on telescope making and observing is Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238. Their catalogue, "Scanning The Skies", is available at no charge. Another souce of teaching and telescope-related materials is MMI Corp., 2950 Wyman Parkway, Baltimore MD 21211.

In the discussion below, an asterisk (*) indicates that we think the telescope looks good for the purpose, but that we have no direct experience with that particular instrument.

I. Elementary Observing Aids

A. Star Finders. A useful device for teaching orientation of the sky and the concepts of right ascension and declination is a "star finder". This term generally denotes a tube (with or without optics), mounted on a simple equatorial mount with simple position readout circles, to point towards and identify bright stars.

The simplest star finder can be built by hand, from cardboard and syrofoam; see the book "Laboratory Exercises in Astronomy" by Holzinger and Seeds (MacMillan, 1976, $6). Commercially available versions (see MMI Corp.) avoid the paper and glue construction.

Some advertisers also sell a star chart with a horizon and "moveable sky", showing which stars are visible at different seasons of the year. This "multi-layered" flat sky chart, although useful, does not illustrate the three-dimensional aspects of right ascension and declination as well as a star-

finder with a sighting tube.

B. Cuffey's Star Finder. The nicest starfinder, for identifying the brighter stars and for teaching orientation in the sky, is the one described by Dr. James Cuffey, in Sky & Telescope, December 1974, page 364. He used 7 x 50 binocular objectives with 45° mirrors and appropriate eyepieces to give a 6° field. These optics were mounted on simple (but effective) right ascension and declination circles, and mounted on a pier. This is a perfect device for teaching coordinate systems, sidereal time, and diurnal motion.

C. Binoculars. A pair of binoculars are very useful for constellation study or location of bright nebular objects. Leavitt and Marshall's "Star Maps For Beginners" (Simon and Schuster) is just about unbeatable for location of the brightest stars in each constellation. Another useful book for use with binoculars is "Astronomy With Binoculars", J. Muirden, ed. (Transatlantic, 1976). A reasonably dark sky and a support for the binoculars will greatly help. High power binoculars are not needed here; 7 X 50's or 10 x 50's are appropriate.

D. Home-Built Telescopes. If you enjoy working with your hands, a high-quality telescope can be built on a budget. Most amateur telescope makers would advise that you begin by acquiring either "Making Your Own Telescope" by A. J. Thompson (Sky Publishing, $5), or "How To Make A Telescope" by J. Texereau (Double Anchor, $2). The classic three volume series Amateur Telescope Making, edited by A. G. Ingalls, is a venerable source of ideas and sound advice. Two words of caution: your own craftsmanship should be realistically evaluated before you begin, and pay serious attention towards obtaining a sturdy mount; probably the most serious drawback of most inexpensive instruments is the lack of a useable equatorial mount. See the advertisers in Sky & Telescope for telescope making kits.

II. Moderately Priced Telescopes

A. Classical Newtonian Reflectors. While this form of telescope has probably been the most popular type of small telescope over the past 50 years, I recommend that you avoid the classical Newtonian telescope for a portable teaching telescope. The primary disadvantages are the long tube (clumsy storage and transport) and the difficulty of obtaining an equatorial mount sturdy

enough to avoid vibrations. In addition, one or both of the mirrors may be knocked out of collimation and image quality suffers accordingly. If you still think you want a classical Newtonian, the Criterion Dynascope RV-6* looks pretty good, with a 6-inch f/8 primary and electric drive, for $280.

B. Refractors. My objections to the classical Newtonian for student instruction mostly apply to refractors also, except that image quality is likely to be better with a refractor, other things being equal. The focal ratio of a refractor is likely to be fairly long (f/10 or more); that's good for observing planets, but not so good for nebular objects. Unitron makes a series of high quality refractors, from 2.4-inch up through 6-inch; prices begin around $300 for the alti-azimuth mounted 2.4-inch. With a telescope of this quality (and long tube), a steel pier buried in concrete is especially desirable. Another approach to acquiring a quality refractor involves buying the objective lens and having a machine shop mount it in a tube, along with an equatorial mount. To realize the potential of this approach requires patience, experience, and a really good machine shop. See the Sky & Telescope advertisers for prices of lenses.

C. C5 and C8 Celestron. Perhaps the most popular of the intermediate priced telescopes are the Celestron 5-inch and 8-inch telescopes. Both telescopes employ Schmidt Cassegrain optics, which means a short tube and a wider useable field of view. Both telescopes come with a fork mount that may be used with Celestron's equatorial wedge, for either table-top use or bolted to a tripod or permanent pier. Many options are made for the Celestron telescopes, including adaptors for 35 mm cameras, heavy tripods, cooled-emulsion camera, and 12 volt converter for the electric drive. Both telescopes have right ascension and declination setting circles built in, electric drive, and a finder scope. The C5 costs about $700, and the C8 is about $1000. Either of these is a very good choice for a medium-priced telescope for classroom instruction.

A lower-priced version of the above telescopes is now available; the C90 employs Maksutov optics and a 3½-inch mirror. It is available with setting circles and an equatorial mount. Price is about $500.

D. Rich-Field Telescopes. Two telescopes will be mentioned in the area of "rich-field telescopes" (or RFT). An RFT is a wide-field, fast f-ratio telescope, designed to show a larger area of the sky, but with very low magnification. This type of telescope is useful for searching for nebular objects and general identifi-

cation of particular stars or regions of the Milky Way; the magnification may be too low to be useful for most planetary observations. Focal ratios are about f/4.

Edmund Scientific Astroscan.* Probably the best known RFT, this has a 4-inch mirror and eyepiece for 16X magnification. The base of the telescope is spherical, and an inexpensive table stand allows swivelling the telescope in virtually any direction. No finder telescope is included, but with the wide field, it is not mandatory. No setting circles. Useful as a low-power telescope, one step above binoculars. About $160.

Coulter CT-100.* A 4½-inch f/3.5 RFT, with carrying case; $80. Fits standard pan-tilt head tripod. An equatorial mount can be added later ($130), and the mirror can be exchanged for an f/8 mirror ($50). No finder telescope and no setting circles. Camera adapter and finder telescope are available as options.

III. Expensive Portables

A. Questar. The most famous high-quality portable telescope is the Questar, available with 3½-inch or 7-inch objective. The Maksutov-Cassegrain optics provide a short, compact tube and superb quality. The effective focal ratio is about f/15, and nebular images may be disappointingly faint. Prices are about $2000 for the 3½-inch Standard Questar (with built-in equatorial mount and electric drive). With the Linhof tripod and electric drive, tracking accuracy is more than adequate for casual observing.

B. Celestron 14.* Although billed as portable, the Celestron 14 (14-inch mirror) is really pretty big for portable use. A permanent pier is almost essential for this size telescope; if no dome is available, the telescope can be carried outside and bolted onto a pier for that night's observing. The quality appears to be appropriate for mounting in a small dome, for general teaching of introductory astronomy courses. Schmidt-Cassegrain optics and the corresponding short tube mean less vibration; the electrical slow motions and accurate setting circles are valuable in finding faint objects.

C. Quantum Four and Quantum Six Telescopes.* A relatively new company, Optical Techniques, Inc., is producing two telescopes with Maksutov folded optics, built-in sidereal drive and setting circles, and finder telescope. The Four (4-inch mirror, $1100) and the

Six (6-inch mirror, $2000) are very high quality telescopes, of the same general construction as the Questar. For use on a sturdy tripod, or on a permanent pier (aligned on the North Pole). The short tube helps avoid vibrations and wind problems, and the fact that the tube is sealed (with a glass corrector plate on the front end of the tube) means that the optics are protected from dust, etc. f/15 optics.

Dr. David L. DuPuy
Department of Astronomy
St. Mary's University
Halifax, N.S.

Editor's Note: The prices quoted in this section are generally those quoted by U.S. suppliers, in U.S. dollars, as of late 1979. Further information can be found in an article "Consumer's Guide to Small Telescopes," by Richard Berry, Astronomy, October 1979.

PERIODICALS IN ASTRONOMY

The following periodicals are useful as reference material for undergraduate astronomy courses. The list does not include research journals, such as the Astronomical Journal and the Astrophysical Journal, which may be useful for advanced astronomy courses. Subscription rates quoted are for one year, as of January 1980.

Astronomy. $18.00 U.S. per annum. AstroMedia Corp., Circulation Services, 411 E. Mason St., P.O. Box 92788, Milwaukee, WI 53272. A glossy, monthly periodical containing non-technical articles and notes on modern astronomy and on the appearance of the sky. Very profusely illustrated.

The Griffith Observer. $5.00 per annum. Griffith Observatory, 2800 East Observatory Road, Los Angeles, CA 90027. An excellent monthly periodical containing non-technical articles and notes on modern astronomy, history and biography, and practical astronomy, well illustrated.

Journal of the Royal Astronomical Society of Canada. $16.00 (individual) or $35.00 (subscription) per annum. R.A.S.C., 124 Merton St., Toronto, Ontario M4S 2Z2. A bi-monthly periodical containing some technical, but many non-technical articles on various astronomical topics, including history, education, biography and developments in Canadian astronomy. The "centrefold" contains additional material in a lighter, more practical vein.

Mercury. $20.00 U.S. (individual) per annum. Astronomical Society of the Pacific, 1290 24th Ave., San Francisco, CA 94122. A bi-monthly periodical containing non-technical articles on modern astronomy (especially the more exotic aspects--spaceflight, exobiology, cosmology), and on historical, biographical and educational topics.

Sky and Telescope. $17.50 U.S. per annum. Sky Publishing Corp., 49-50-51 Bay State Rd., Cambridge, Mass. 02138. An excellent monthly periodical containing semi-technical and non-technical articles and news notes on astronomy, spaceflight, telescope making and astronomical observing. Profusely illustrated. High-quality material, but not quite as "beautiful" as Astronomy.

Star and Sky. $15.00 U.S. per annum. 44 Church Lane, Westport, Conn. 06880. P.O. Box 5172. A relatively new publication, now edited by Canadian astronomy writer Terence Dickinson. Authoritative, non-technical articles on general astronomy with some emphasis on observational topics.

The following general periodicals are also very useful, as they frequently contain timely articles on astronomy.

Science News. $18.50 per annum. Science Service Inc., 1719 N. St., N.W., Washington, D.C. 20036. A concise weekly summary of current developments in science, written at a non-technical level.

Scientific American. $18.00 per annum. Scientific American, Inc., 415 Madison Ave., New York, N.Y. 10017. An excellent periodical containing authoritative, well-written review articles on current developments in science.

ADDITIONAL SOURCES OF INFORMATION

1. The Canadian Astronomical Society, Education Committee, is engaged in several projects related to the teaching of astronomy, including the production of these "Source Materials". The committee sponsors a bi-monthly "Education Notes" column in the Journal of the R.A.S.C., edited by Drs. S. Demers and D.L. DuPuy. Comments about and contributions to this column would be appreciated. The members of the committee (see forward) would be willing to provide advice and assistance (within reason) with problems related to the teaching of astronomy.

2. The Royal Astronomical Society of Canada, 124 Merton St., Toronto M4S 2Z2, publishes a useful bi-monthly Journal and National Newsletter, and an indispensable annual Observer's Handbook (see section on this topic). The Society has 18 centres or branches across Canada, whose activities can provide enrichment for student and teacher alike.

3. The American Astronomical Society, Task Group on Education in Astronomy (TGEA), aids in the teaching of astronomy and serves as a medium for distributing up-to-date information on astronomical teaching materials. A newsletter is issued as material warrants, with new information and references. The TGEA Newsletter is available from AAS Education Office. Sharp Laboratory, University of Delaware, Newark, Delaware 19711. The efforts of the TGEA constitute a valuable source of ideas and inspiration for teaching.

4. The Association of Astronomy Educators is a relatively new organization which seeks to advance the teaching of astronomy at all levels. The AAE is affiliated with the National Science Teachers' Association, and sponsors short courses and a useful semi-annual newsletter. Annual dues are $1.50 U.S.; address is c/o D.W. Sunal, Dept. of Curriculum and Instruction, 604 M. Allen Hall, West Virginia University, Morgantown, WV 26506.

5. The Astronomical Society of the Pacific is a world-wide non-profit astronomy education group, founded in 1889, which brings together professional astronomers, teachers and amateurs and makes available information about all facets of astronomy and space science.

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Astronomy in the Classroom - Some New Resource Material

John Percy

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Although there is no formal course in astronomy in the Ontario school curriculum, there are many ways in which this subject can be introduced into the classroom. A unit in astronomy would be a stimulating addition to a course in general science, mathematics, physics and geography, and would be an obvious part of the inter-disciplinary "Space and Man" course. This article describes some new resource materials which might be of interest to teachers.

TEXTBOOKS

Holt, Rinehart and Winston of Canada have published a set of three textbooks on astronomy, at three different levels. Astronomy (Examining your Environment Series) by MacBean, Stecher, Wentworth and Couchman, is an activity-oriented book at the grade 7 or 8 level. A Universe to Explore (Searching for Structure Series) by Ewers and Ewers, continues the activity approach, but at an intermediate level. Finally, Motion in the Heavens (Physics: A Human Endeavour Series) by Paul, Pierce and Stief, examines the historical and philosophical basis of our present understanding of planetary motions.

All three books have considerable merit, and should be considered as possible guide books for a unit on astronomy.

THE STARS BELONG TO EVERYONE

Looking for an effective but different textbook? Why not use "The Stars Belong to Everyone" (subtitled "How to Enjoy Astronomy"), written by Toronto astronomer Helen S. Hogg and published last year by Doubleday. This book was honoured by being included in Scientific American's Christmas guide to science books for young people; with its delightful style and its emphasis on observation with the unaided eye, it would make an excellent guide book for astronomy at any level.

OTHER RECENT BOOKS

Books on astronomy are many, and varied in quality. The following are some of the best and most interesting in recent years, and should be in every school library. (Quick, send your librarian a copy of this article!) Almost all of these books are now available in a soft-cover edition.

"Realm of the Universe", George Abell (Holt, Rinehart and Winston, 1976). The standard beginning textbook on astronomy.

"The Galactic Club", Ronald Bracewell (W. H. Freeman, 1974). An objective, interesting discussion of the possibility of intellignet life elsewhere in the universe.

"The Violent Universe", Nigel Calder (Futura, 1969, more recently in paperback). Based on a superb BBC-TV documentary on the revolutionary discoveries in astronomy in the 1960's.

"Quasars, Pulsars and Black Holes", F. Golden (Scribner's, 1976) An exciting book on topics which lie at the forefront of modern astronomical research.

"The Amazing Universe", Herbert Friedman (National Geographic Society, 1975). A well-written and superbly-illustrated account of modern astronomy.

"Relativity and Cosmology", W. J. Kaufmann (Harper and Row, 1976) A good introductory book on these topics: non-technical but by no means "easy".

"The Cosmic Connection", Carl Sagan (Doubleday, 1973) Voted "science book of the year", a provocative, idea-filled book on space exploration and on the possibility of life elsewhere in the universe.

"The Solar System", (W. H. Freeman, 1976) A collection of articles which appeared in a special issue of Scientific American in September 1975.

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"Black Holes, Quasars and the Universe", Harry Shipman (Houghton-Hifflin, 1976). A slightly more technical book, but one which will be appreciated by teachers and students who want to get their teeth into these subjects.

SINGLE-TOPIC BOOKLETS

The American Astronomical Society's Task Group on Education has recently produced a set of four single-topic booklets for use in the schools. Each booklet was written by an active professional astronomer, was reviewed by a penal of other astronomers and educators (including many high school teachers) and was then tested in teacher workshops. The booklets include questions, discussion topics, projects, references, glossaries and some excellent diagrams and photographs. The booklets are aimed at a middle high school level but - since they are intended for the teacher rather than for the student - they can be adapted to just about any level.

The booklets are: The Supernova: A Stellar Spectacle by W. C. Straka (NAS-1-19-126, $1.30, pp 37), Chemistry Between the Stars by R. H. Gammon (NAS-1-19-127, $1.60, pp 59) Atoms and Astronomy by P. A. Blanchard (NAS-1-19-128, $1.20, pp 31) and Extragalactic Astronomy: The Universe Beyond Our Galaxy, by K. C. Jacobs (NAS-1-19-129, $1.30, pp 38). These books can be ordered by title and code number from the Superintendant of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

ASTRONOMY ACTIVITIES PACKAGE

The originators of the single-topic booklets have also developed a set of astronomy activities for use at the grade 7 to 12 level. The material is listed below, and Canadian readers can obtain single copies of each activity by sending a stamped, self-addressed envelope to John R. Percy, Department of Astronomy, University of Toronto, Toronto, Ontario, M5S 1A7, stating which activity they wish to receive. They are then free to reproduce the activities for their own use, provided only that they retain the "credit line" given on each sheet.

The activities package was compiled by Dr. Paul H. Knappenberger, Jr., Science Museum of Virginia, Governor St., Richmond, Virginia, 23219, and was sponsored by the Association of Science and Technology Centres and by the National Science Foundation.

With the exception of those noted, the activities are all suitable for grades 7 to 12. Activities 1, 3 and 5 to 8 are outdoor activities.

1 Observing the Big Dipper and Locating the North Star
2 The Big Dipper in Three Dimensions
3 Making and Using an Astrolabe
4 Retrograde Motion of Mars
5 Measuring the Sun's Diameter
6 Finding the Sun's Altitude
7 Finding the Sun's Azimuth
8 Observing Sunspots
9 The Sunspot Cycle
10 Classifying Stars (grade 11, 12)
11 Expanding Universe Model (grade 11, 12)
12 Astronomy Word-Finding Puzzle
13 Celestial Cross-Word Puzzle
14 Spectroscopy Puzzle (grade 11, 12)
15 Earth Science for Martians

SPACE FOR WOMEN

What are the opportunities - and problems - which face women embarking on a career in science? This is a question of concern to both teachers and students. The 46 page booklet "Space for Women" is an outgrowth of a symposium on that topic; it is clear, concise and honest, and - although it deals specifically with careers in astronomy, earth and space science - its conclusions apply equally well to other fields. Single copies of the booklet can be obtained, free of charge, from The Women's Program, Center for Astrophysics, 60 Garden Street, Cambridge, Mass. 02138, U.S.A.

CAREERS IN ASTRONOMY

The best general pamphlet on this topic is still the one prepared by Dr. John F. Heard for the Guidance Centre, University of Toronto. This pamphlet should be in every school guidance office.

FILMS AND SLIDES

Visual aids remain a problem in teaching astronomy: there are no good inexpensive films (though NFB's Universe is not as out-of-date as it seems), and most filmstrips contain unnecessarily-pedantic material. The only comprehensive supplier of slides is Tersch Enterprises, Box 1059, Colorado Springs, Colorado 80901, U.S.A. Their new slide set "U" has about 100 slides for about $70., and is highly recommended. The McLaughlin Planetarium supplies slides from the Palomar Observatory: the quality is excellent but the range of topics is rather narrow.

Of course, the best resources for the teaching of astronomy are keen students, a keen teacher and lots of clear nights.

Good luck!

Star Stuff

Astronomy in your Classroom

by John R. Percy
Professor of Astronomy

If you teach astronomy (a lesson, a unit, a course) in your classroom (science, mathematics, geography...) and if you would like advice or assistance regarding the teaching of astronomy, then perhaps I can help. I am chairman of the education committee of the Canadian Astronomical Society, and association of professional astronomers in Canada, and one of our goals is to advance the teaching of astronomy in the schools. My own background includes training as a professional astronomer, educator and resource person for teachers. I can provide advice and assistance (within limits) on specific problems. I can also provide single copies of the material listed below. Please send a 9" x 12" self-addressed envelope, and a note stating which material you want. Production and distribution of this material is made possible by a grant from Erindale College, University of Toronto.

1. "Education in Astronomy: A Review"; reprinted from the Journal of the Royal Astronomical Society of Canada (JRASC), 70. 277-291 (1976).

2. "The Teaching of Astronomy in Canadian Schools"; reprinted from the JRASC, 74, 81-87 (1980). This is the text of an address given to teachers and astronomers at the General Assembly of the International Union, 1979.

3. "Source Material for the Teaching of Astronomy; 2nd Edition": PUBLISHED BY THE Education Committee, Canadian Astronomical Society, Feb. 1980, pp. 45. This booklet deals mainly with introductory astronomy courses in colleges and universities, but would be useful at the intermediate and senior level in high school. In addition, a French-language version is available.

4. "Astronomy in the Classroom: Some New Resource Material"; reprinted from Crucible: The Journal of the Science Teachers' Association of Ontario, May, 1977, pp. 2. This article describes among other things three useful text books (available from Holt, Rinehart and Winston of Canada) and four useful single-topic booklets on "The Supernova", "Chemistry Between the Stars", "Atoms and Astronomy" and "Extragalactic Astronomy", (developed by the Americal Astronomical Society and available from the U.S. Government Printing Office).

5. "Educational Material in Astronomy Produced and Distributed by Canadian Obvservatories, Museums and Planetariums"; reprinted from the JRASC, 72 (1978), pp. 2. In particular, the Astronomy Department of the National Museum of Science and Technology, 1867 St. Laurent Blvd., Ottawa K1A 0M8 publishes useful leaflets, star maps and a monthly sky guide.

6. Set of six star maps for use at southern Canadian latitudes. Teachers are free to reproduce these for use in the classroom.

7. "Astronomy Activities Package": a set of astronomy activities for use at the grade 7 to 12 level. This material was compiled by Dr. Paul H. Knappenberger, Science Museum of Virginia, Governor St., Richmond, Virginia 23219, and was reviewed and tested in teachers' workshops.

   The package was sponsored by the National Science Foundation and by the Association of Science and Technology Centres. The material is listed below. Readers may obtain single copies as described above. They are then free to reproduce the activities, for their own use, provided only that they retain the "credit line" given on each sheet. (1) Observing the Big Dipper and Locating the North Star (2) The Big Dipper in Three Dimensions (3) Making and Using an Astrolabe (4) Retrograde Motion of Mars (5) Measuring the Sun's Diameter (6) Finding the Sun's Altitude (7) Finding the Sun's Azimuth (8) Observing Sunspots (9) The Sunspot Cycle (10) Classifying Stars (11) Expanding Universe Model (12) Astronomy Work-Finding Puzzle (13) Spectroscopy Puzzle (14) Celestial Crossword Puzzle (15) Earth Science for Martians. Activities 10, 11 and 13 are for senior grades.

8. "The Royal Astronomical Society of Canada": a pamphlet describing this very worthwhile scientific and educational society, and how you can join your local branch.

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EDUCATION IN ASTRONOMY: A REVIEW*

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Abstract

The health of astronomy depends crucially on education in astronomy for two reasons: the education *of astronomers* helps to determine their competence and their attitudes, and the education *of non-astronomers* eventually influences the climate (financial and otherwise) in which astronomers operate.

This paper touches briefly on several aspects of education in astronomy, but concentrates on the following purposes: (i) to review the education programmes of some astronomical societies (the IAU, RAS, AAS, ASP, RASC, etc.); (ii) to indicate which material from these programmes is useful and available to Canadian astronomers and (iii) to suggest some worthwhile *new* projects which might be carried out by Canadian astronomers.

Introduction. The topic of education is of importance to astronomers for two reasons. The education *of astronomers* determines their competence and attitudes, hence determines the internal health of astronomy. The education *of the public* in astronomy determines the level of public understanding and support (financial and otherwise), hence determines the climate in which astronomers operate.

Professional education is a concern for all sciences. Public education is a *special* concern for astronomy. This is because public interest is so high – and so misguided at times – that astronomers have both a special opportunity and a special responsibility. Astronomy provides the public with an excellent lesson about what science is and what science does, though first, the astronomer must make his voice heard above those of the astrologers and other popular pseudo-scientists. It is tempting to leave this task to the professional educators, in the planetariums, schools and the media; however, it is both unwise and unfair to do so entirely.

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What can the astronomer do to further education in astronomy? Basically, three things: (i) be education-minded; aware of local needs and opportunities; (ii) be aware of existing education programs and material, and use this material where possible; and (iii) contribute to and publicize a *small* number of worthwhile new projects. The purpose of this paper is to elaborate on these three possibilities.

Existing Programs and Material. Hundreds of organizations are already engaged in education in astronomy. These include international, national and local scientific and educational societies in many countries. These all produce some useful material; the task of the astronomer is to track it down, evaluate it, and use it. Geographic and linguistic diversity and isolation are the two greatest barriers to this process.

The International Astronomical Union, through its Commission 46 (The Teaching of Astronomy), contributes to education in astronomy. The work of the commission is severely limited by available funds and manpower, and by local diversity and isolation. Still, the commission has carried through several projects, particularly aimed at developing countries. (i) *Project Contratype* assembles and distributes photographs, diagrams and other material for teaching. The small amount of material available, and the difficulty of distribution and billing, have limited the scope of this project. (ii) The commission encourages and supports summer schools for young astronomers, especially from developing countries. (iii) The commission encourages liaison between astronomers and school teachers. (iv) The commission has assembled an extensive but not very selective list of astronomy materials for teaching. T. L. Swihart (Steward Observatory, University of Arizona, Tucson, Arizona 85721) has prepared a supplement 1970–1973 to this list. The present chairman of Commission 46 is Dr. D. McNally, University of London, England, and the Canadian representative is Dr. J. Climenhaga, University of Victoria.

Aside from supporting Commission 46, astronomers can contribute to education in developing countries in other ways. For example, Canadian astronomers have given lectures and courses at universities in Argentina and Chile, while present in South America for research purposes. Several astronomy graduates have taught in developing countries for extended periods of time, as volunteers in C.U.S.O. or similar organizations. These people may be the only trained astronomers for hundreds of miles, and it is important that they be given encouragement, training and experience in teaching as part of their graduate work, and that they have access to the necessary resource material.

The Royal Astronomical Society, London, England, has been directly involved in education only since 1973. Prior to that time, astronomical education was carried out on a much more limited scale than in North America. Recently, astronomy has been introduced in several universities and teachers' colleges, and there is a high-quality course in astronomy in the secondary schools.

The major projects of the R.A.S. Education Committee (also under the chairmanship of Dr. McNally) are: (i) Twelve "units" in introductory astronomy, for use in the schools and teachers' colleges. The Nuffield Foundation has supported this project and the units will presumably be available – complete with notes, experiments and slides – for use in Canada as well as the U.K. (ii) Regional resource centres, to supply teachers with equipment and teaching aids. (iii) Young Persons' Lectures, to be given (live and on TV) by distinguished astronomers. (iv) Museum displays. (v) A brochure on graduate astronomy programs in the U.K. (vi) A broadsheet on general astronomy, to be distributed, on request, to schools and the public. [The R.A.S.C. once published a similar broadsheet called "Sky Facts", and the National Museum of Science and Technology publishes an excellent series of leaflets on selected topics in astronomy.] (vii) The production of slides for purchase by teachers.

The above list is given in order to illustrate the types of projects undertaken by one astronomical society; further details are given by McNally (1975).

The American Astronomical Society (211 FitzRandolph Rd., Princeton, N.J. 08540) has had a committee on education for many years, but its involvement in education has increased considerably since about 1969. About that time, a special Task Group on Education in Astronomy (T.G.E.A.) was formed. Because of the close relationship between Canadian astronomers and the A.A.S., the activities of the T.G.E.A. are of particular relevance in Canada. The main "tasks" of the T.G.E.A. are the following: (i) Conferences on the teaching of astronomy, held in conjunction with A.A.S. meetings; the proceedings have been published (Berendzen 1972, Jettner 1970, Ross 1969). Sessions on education are now held regularly at A.A.S. meetings, and the abstracts are published in the *Bulletin* of the A.A.S. (most recently, *Bull. A.A.S.*, 7, 446, 1975; 8, 342, 1976). (ii) Newsletters, containing information and lists of resource material (laboratory exercises, for instance). These are co-ordinated by Dr. G. Verschuur (Fiske Planetarium, Boulder, Colo. 80302) and Dr. D. Wentzel (Astronomy Program, Univ. of Maryland, College Park, Md. 20742). (iii) A collection of syllabuses for astronomy courses for non-science students, pres-

ently maintained by Dr. J. Wertz (4100 Crosswick Turn, Bowie, Md. 20715). (iv) A roster of consultants on astronomy education [might the C.A.S. not do the same?]. (v) Four brochures on selected topics on astronomy, produced under the sponsorship of N.A.S.A., for use in secondary schools. A "package" of 11 student activities has also been developed, under the sponsorship of N.S.F. Workshops have been held to develop and evaluate these materials (Smith and Knappenberger 1975, 1976). These projects were carried out under the direction of Dr. Paul Knappenberger, Science Museum of Virginia, 217 Governor St., Richmond, Va. 23219. These materials will soon be available for use in schools in the U.S. and Canada. (vi) A program of astronomy for the national parks. [A similar program has been carried out by members of the R.A.S.C. Toronto Centre (Gada 1976).] (vii) A prototype travelling exhibit for schools and planetariums, presently under development. (viii) The Shapley Lectures, given at small colleges and universities by distinguished astronomers. Further information about the education projects of the A.A.S. is given by Wentzel and Verschuur (1974).

The American Association of Physics Teachers has published several resource letters, the most indispensable being an annotated guide to college-level teaching materials: EMAA-1 "Educational Materials in Astronomy and Astrophysics" (Berendzen and DeVorkin 1973), available from the A.A.P.T., Drawer AW, Stony Brook, N.Y. 11790 for $0.50.

The Astronomical Society of the Pacific (1244 Noriega St., San Francisco, Calif. 94122) has recently undertaken an expanded program of activities in public education: workshops and conferences for teachers, a newspaper column on astronomy, a radio program, tapes on astronomical subjects, an astronomy "hot line" telephone service and a series of interdisciplinary reprints for high schools and colleges. The A.S.P. journal *Mercury* contains trendy (but useful) material of an educational nature.

The Griffith Observatory (2800 East Observatory Rd., Los Angeles, Calif. 90027) publishes a more conservative but equally-useful journal: *The Griffith Observer*.

The Royal Astronomical Society of Canada (124 Merton St., Toronto, Ontario M4S 2Z2), with 18 centres across Canada, has been active in education since before the beginning of this century. The contributions of the R.A.S.C. to public education at the local level are numerous and diverse: public lectures, courses, discussion groups, displays, films, star nights, observing and telescope-making sessions, publications, assistance to schools and other youth groups. The R.A.S.C. provides one solution to the problem of the local nature of education needs, and it provides a convenient vehicle

whereby professional astronomers can work with the public. Professional astronomers owe the R.A.S.C. their support, through encouragement, assistance and membership.

At the national level, the R.A.S.C. contributes to education through its publications: the *Journal* and the *Observer's Handbook*.

The *Handbook* is a valuable aid for students and teachers in secondary schools and universities, and is essential for anyone pursuing astronomy in a serious way. It can be used as a general reference, as an aid to carrying out observational activities, and as a source of material for laboratory exercises.

The *Journal* contains review articles, articles on biographical, historical and educational topics and on Canadian astronomy; it also contains shorter notes on a variety of topics of interest to students, teachers, amateur and professional astronomers.

Because the *Journal* serves both amateurs and professionals, it suffers at times from a split personality! A worthwhile and coherent direction which the *Journal* might take in the future is toward an emphasis on *education*. In addition to attracting scholarly but non-technical articles on general topics, the *Journal* might carry a regular column of *Education Notes*. This column would contain annotated lists of books, articles and other educational materials, information on educational programs in schools and universities, descriptions of demonstration or laboratory apparatus, and short articles and notes on education. Readers who have suggestions or contributions for such a column should send them to John R. Percy, Department of Astronomy, University of Toronto, Toronto, Ontario M5S 1A7.

The National Research Council, Associate Committee on Astronomy, Subcommittee on Education, was formed in 1971. [In its first report (November 1971), it noted that N.R.C. is not normally involved in matters of education – a topic which is more appropriately considered by the Canadian Astronomical Society. Nevertheless, five years later, this anomaly still exists.]

In its first report, the subcommittee suggested ten projects which Canadian astronomers, through the subcommittee, might undertake:

(i) "A booklet listing astronomy programs available at Canadian universities should be prepared and distributed ...". Some of this information is available in the A.A.S. brochure "A Career in Astronomy" (211 FitzRandolph Rd., Princeton, N.J. 08540), and in an excellent Canadian brochure "Astronomer" (Guidance Centre, 1000 Yonge St., Toronto, Ontario M4W 2K8). The latter brochure is especially useful, as school teachers and guidance counsellors have little direct knowledge of astronomy as a career.

Information on graduate programs has already been published in the C.A.S. newsletter *Cassiopeia* (1, Autumn 1973). This information should be frequently updated and republished (in *Education Notes*, for instance).

(ii) "The National Film Board, and other organizations, should be encouraged to produce additional astronomy films for use in schools, universities and for the general public." The best of the several astronomy films from N.F.B. is "Universe", used widely in Canada and elsewhere, but now 15 years out of date. A new version of "Universe" (30 minutes, in colour) would be a valuable addition to the world supply of astronomy films.

(iii) "The I.A.U. and A.A.S. lists of astronomy books and related materials should be more widely distributed ...". This proposal is presently being carried out by the subcommittee: an "education package" is being sent to colleges and universities across Canada. Future additions and revisions to the "package" could be published in *Education Notes*.

(iv) "A channel should be established for the exchange of information on education in astronomy ...". This function could be filled effectively by *Education Notes*, and by occasional sessions on education at meetings of the C.A.S.

(v) "A program of visiting lecturers should be established." In June 1976, the C.A.S. agreed to participate in the A.A.S. Shapley Lecture program. Distinguished Canadian astronomers would be included in the program, and they along with other distinguished astronomers would give public lectures at Canadian universities and colleges, particularly those at which no astronomy program exists.

The benefits from a visiting lecture program go far beyond the lectures themselves. The visitors can become aware of the state (or non-state) of astronomy at the host institution; they can advise the faculty and administration about courses, programs and equipment, and they can make contact with potential astronomy graduate students at the institution. In this way, the visitor establishes a two-way link between the astronomical community and the host institution.

(vi) "Courses in astronomy should be organized for school teachers." This is being done locally in many parts of Canada, and several correspondence courses in astronomy are now available; these will be discussed elsewhere in this paper.

(vii) "The role of Canadian planetaria in educating the public ... should be examined carefully." The Planetarium Association of Canada, by its very existence, carries out this proposal; closer liaison between the P.A.C. and astronomers in Canada is desirable and has already begun.

(viii) "An effort should be made to convince science faculties at Canadian universities of the value of astronomy courses in attracting students to the physical sciences." Many universities, for one reason or another, either have no astronomy courses, or have astronomy courses taught by non-astronomers. The former situation is unfortunate as there is considerable interest in astronomy on the part of students; the latter situation is probably better than the former, but is still not ideal. The subcommittee is prepared to assist non-astronomers by providing information (the "education package") and advice, but the process of convincing *every* university to teach astronomy is not as simple.

(ix) "N.R.C. should make a study of the criteria used in awarding scholarships and fellowships."

(x) "In awarding research grants, N.R.C. should carefully consider how the distribution of available funds will affect the quality of education as well as the quality of research at Canadian universities."

The subcommittee is still active and enthusiastic, and is presently involved in several projects: the "education package", C.A.S. education sessions, and *Education Notes*. Its chairman is Dr. D. L. DuPuy, St. Mary's University, Halifax, N.S. B3H 3C3.

What Should and Can Be Done. In the preceding section, some existing programs and material were described. Let us now ask (i) what *should* be done, (ii) *has* it been or *is* it being done, (iii) if so, where is it written up or available, (iv) if not, *can* it be done, given the available funds and manpower? *If* it is to be done, it should be widely publicized and distributed, so that the effort is put to the greatest possible benefit.

At the Professional Level. The professional astronomer – at least in theory – constantly engages in self-education: reading, consulting with colleagues, attending conferences. Nevertheless, all of us must admit that our knowledge of math and physics – and even some areas of astronomy – gradually slips away, and we must constantly be education-minded to counteract this tendency. The C.A.S., with its diverse membership, small meetings and serial rather than parallel paper sessions, helps considerably to broaden the education of its members.

More organized professional education is available in the form of "institutes", such as those sponsored by N.A.T.O., the Aspen organizing committee, and the University of Toronto. The C.A.S. might well consider sponsoring a N.A.T.O.-type institute, as a means of bringing together young astronomers from all parts of Canada. There are several attractive conference centres which would be ideal for the purpose.

joint courses with faculties of education, either at the professional or graduate level. At Toronto, this cooperation has taken the form of occasional guest lectures in science-methods courses: but an M.A. (teaching) program is now being developed, with graduate courses in integrated science. These may allow direct participation by graduate departments of astronomy.

Contact with teachers, via the board science co-ordinator, usually takes the form of "workshops", short courses a few hours in length. These are valuable in that they provide teachers with some concrete resource material, some contact with a real astronomer and – most of all – some confidence.

Astronomy at the Secondary School Level. Astronomy can serve a special role in the secondary schools, enabling the student "to understand the vital need for the tools of physics and mathematics" and to "develop wonder and curiosity very much needed to motivate honest enthusiasm for the sciences" (Szathmáry 1976). Astronomy courses are springing up in many schools across the country, but the nature of these courses varies considerably from class to class, school to school, board to board and province to province. As a result, there is no simple channel of communication to the teachers. [In Great Britain, by contrast, there is a set curriculum for O-level astronomy, and good textbooks have been developed for the curriculum; Haysham (1971), for example.] In Ontario, there is an "interdisciplinary" course called "Space and Man", in which the students can study anything from orbital dynamics to science fiction. A senior-level unit on "Motion in the Heavens" is being studied in some schools, and a good Canadian textbook has been developed for this unit (Paul *et al.* 1976). At a lower grade level, there is sufficient flexibility in the science curriculum so that a unit on observational astronomy can be studied, and a suitable textbook for this unit has also been developed (Ewers and Ewers 1976). A textbook designed for the grade eight level (McBean *et al.* 1973) completes the excellent set of astronomy textbooks published by Holt, Rinehart and Winston. At the primary and junior level, the series of books by Rockcastle *et al.* (1972) is highly recommended. Incidentally: why not more Canadian content in the illustrations for textbooks and articles? Canadian observatories have excellent photographs in their collections; these should be publicized and used more!

These curricula and textbooks, and other resource material which leads to good astronomy in the classroom, have the advantage of wide and continued usage. However, this material did not appear from nowhere, but was prepared, helped along or improved by astronomers. Much school material is prepared by individuals with little or no astronomical training, and the help of a professional astronomer in consulting, reviewing or evaluating

is both worthwhile and appreciated. "Space and Man", and the three Holt, Rinehart and Winston books mentioned above, all involved many man-hours of consultative work. Unfortunately, the local nature of school curricula means that this work cannot be standardized even at a provincial level, and many astronomers can expect to get "roped in" to helping on a local level. There are many contributions which can be made: participating in workshops and in meetings of science teachers' associations, contributing articles to the newsletters of such associations, to science teachers' journals (e.g. *The Science Teacher, The Physics Teacher, School Science, Science and Children*) and to popular magazines (e.g. *Scientific American, Sky and Telescope*), advising on curricula, textbooks, films and slides, and acting as a source for materials produced by the A.A.S. and other astronomical societies. Clearly, not every astronomer could or should do all of these things! The important thing is to do one or two, and be sure that the results of this effort are widely known and used.

Astronomy at the Elementary School Level. It is at this level that most people have their first, and last, formal encounter with astronomy (though in our present system it is quite common for students *never* to encounter astronomy: such are the ways of cafeteria-style education).

I do not envy the elementary school teachers setting out to teach astronomy! It is unlikely that they have had any formal training in astronomy, beyond the "seasons, tides and eclipses" of their own elementary school days. Now they are expected to conduct an inquiry-oriented, activity-oriented unit in a subject quite unsuited to (daytime) activities ["the stars come out at night, the children don't..."]. They may be expected to answer their students' questions on black holes, red shifts and green men, as well as commenting intelligently on a student's "independent research" on such topics as stellar evolution. Small wonder that many teachers avoid astronomy entirely! Nevertheless, I have seen dozens of teachers working tirelessly, coming out to workshops on evenings and weekends, tackling not-so-easy university courses in astronomy, just to get a better mastery of astronomy and how to teach it.

The planetariums, where they exist, play a major role in bringing astronomy to elementary school students (or *vice versa*, to be more precise). Even where they do *not* exist, planetariums can help; the Winnipeg planetarium, for instance, produces some very useful "fact sheets" on astronomy; other planetariums produce similar material, act as suppliers of books and other materials, or simply provide valuable advice.

The role which the professional astronomer can play depends very much on his own interests and on the time he has available, and on the nature

of the local educational system. Many observatories and astronomy departments have active programs of school and public liaison; these programs depend on the encouragement and support of professional astronomers. Workshops are always valuable, and these are usually arranged by the local science coordinator – a good person to contact and to get to know. *Education Notes* would offer a useful channel for occasional publication of lists of books, articles, activities, apparatus and aids for the teaching of astronomy in elementary schools.

Astronomy Education and the General Public. "The general public" can be divided into categories ranging from those who are keenly interested in astronomy, through those who are amenable to learning about astronomy, to those who have no interest, or potential interest, in the subject. The first group is probably well taken care of by the many books, articles, magazines and lectures on the subject, and it is this group which gives the astronomer such a feeling of satisfaction when he becomes involved in public education. The last group represents an almost insurmountable challenge to the astronomer, as they would pass over the most interesting astronomy material to find their daily horoscope. It is the middle group – which numbers many million people in Canada – which provides a worthwhile challenge to the astronomer. When we realize that nearly a million people visit planetariums each year, and an equal number read the Toronto *Star* (for example) each weekend, we are aware of the possibilities which exist.

The planetariums, the press, radio and television are the major vehicles of public education in astronomy, with the R.A.S.C., observatories and departments of astronomy playing a significant but smaller *direct* role. [The *indirect* role which astronomers play is much greater, but varies considerably and is more difficult to define.]

Astronomy and the Planetariums. The planetariums are the special public-relations departments of the astronomical community, and it would be impossible to discuss fully their problems, achievements and potential in a short article like this one. This country is fortunate to have more fine planetariums per square Canadian than any other country. By and large, these planetariums provide good entertainment and education, and they are able to maintain and improve their performance through the Planetarium Association of Canada (President: D. Rodger, MacMillan Planetarium, 1100 Chestnut St., Vancouver, B.C. V6J 3J9). Closer liaison between astronomers and the planetarium fraternity can and should be achieved, by attendance at each other's professional meetings, by periodic reports from the P.A.C. in

this JOURNAL, and by articles and reports from professional astronomers in the P.A.C. journal *North Star*. For instance, the public is always interested in current developments in Canadian astronomy, so a "popular" summary of the work presented at C.A.S. meetings would be in order.

Since the opening of the McLaughlin Planetarium in Toronto, the University of Toronto has frequently used special planetarium shows as part of its introductory courses. Planetarium staff teach several credit and non-credit courses to students and the public. Many universities in Canada have a planetarium at hand, which can be a useful tool in undergraduate teaching; such an arrangement also creates a closer liaison between professional astronomers and the planetariums. There are many other areas of astronomy education in which astronomers and planetarium staff can work together.

Astronomy Education and the Press. Although astronomers are aware of the power of the press, they are generally not aware of how to exploit it. Lydia Dotto, science writer for the Toronto *Globe and Mail*, provides the following advice. Although astronomy probably has wider public appeal than any other basic science, it is not considered "hard news" by the press; furthermore, there are very few active science writers in Canada. For this reason, astronomy news items often fall on infertile ground. The essential step in astronomy education through the press is a *personal contact* between interested, articulate astronomers, and equally interested, knowledgeable reporters. At each astronomical institution, at least one astronomer should assume a personal responsibility for public relations. He should seek out a suitable contact person at the local newspaper, radio or TV station. This person may be a science writer; more likely he will be a general reporter with an interest in astronomy. Without this personal contact, news flow through press releases, for instance, is likely to be inefficient or completely non-existent.

There exists a Canadian Science Writers' Association; *Education Notes* should endeavour to circulate a list of active science writers who would be interested in receiving news of important advances in astronomy. There is also a very useful publication called "Selected Press Clippings", distributed free of charge by the Information Department, National Research Council, Ottawa; this publication contains copies of articles on science and technology appearing in the major Canadian newspaper and magazines, and is an excellent resource for school and university teaching.

The Popularization of Astronomy. Rather than induce a journalist to

"Sabbatical leave" is a valuable form of continuing education for professionals, and we must resist the creeping tendencies of government to downgrade or eliminate this process.

At the Graduate Level. Graduate education is a process which is usually dealt with by individual universities in their own way; there has not been a major conference on the subject since 1962 (at Indiana U., sponsored by the A.A.S.). Nevertheless, in this age of tight budgets and variable job opportunities, some degree of cooperation is desirable. Some transfer of ideas takes place through individual contacts, especially where the graduate faculty of a university is drawn from many other institutions. A session on "graduate education" would be a worthwhile addition to a future C.A.S. meeting; it might even attract some of our colleagues from the U.S.A.

The most oft-discussed aspect of graduate education is that of manpower and placement (Roeder and Kronberg 1970). The job market in astronomy is variable in an unpredictable way, and graduates may find themselves teaching in a small college, working in a planetarium or having no astronomical job at all. Astronomers generally agree that graduate students should prepare for this eventuality by receiving a broad background in math and physics, and by taking advantage of all teaching-related opportunities which arise in their universities and in nearby schools and planetariums. Astronomers do *not* agree on whether graduate enrolments should be closely tied to the job market, or on whether prospective graduate students should be warned about the possible job prospects when they graduate. Surely – despite the job situation – we must try to recruit the *best* possible students into graduate studies in astronomy.

The C.A.S. maintains an employment register (presently c/o Dr. John B. Rice, Brandon University, Brandon, Man. R7A 6A9); graduates *seeking* employment or institutions *offering* employment are urged to notify the register about their needs.

The C.A.S. has also published an outline of graduate astronomy programs at Canadian universities (*Cassiopeia*, 1, Autumn 1973); this outline should be frequently updated, and widely circulated.

At the Undergraduate Level. There is no shortage of literature and resources on education in astronomy at the undergraduate level; the main problem is to keep abreast of all that has been done! The excellent compilations by the A.A.S. and the A.A.P.T., for instance, have already been described. However, there is a constant need to update these compilations, and *Education Notes* in this JOURNAL could serve a useful function by doing this.

Although the A.A.S. holds regular education sessions, there is still a place for such sessions at meetings of the C.A.S., both to deal with local topics, and to deal with topics in a more structured way. At least one Canadian university (my own) is currently re-examining and re-organizing its undergraduate courses and programs; an education session on the specific topic of "undergraduate courses and curricula" would allow universities to share their views and experiences with each other and with smaller universities starting or building up an astronomy program.

A brief listing of undergraduate astronomy programs in Canadian universities should be compiled, published in *Education Notes*, and reprinted. It would be useful not only to universities but also to planetariums, departments of education, school boards, etc.

The C.A.S. at one time considered offering a nation-wide award for excellence in undergraduate astronomy, but the idea was dropped because of the difficulty in comparing students from different universities.

Astronomy is taught at very few junior and community colleges, although there is great need and potential here. Seneca College, near Toronto, has a planetarium offering public and school shows, and a well-developed program of courses; these are given by two teaching masters with considerable background in astronomy. The courses are taught under the heading of "liberal arts", a heading which also exists at most other community colleges. Astronomy courses can be designed in such a way as to provide not only course content, but also specific skills: teaching, and designing audio-visual presentations, for instance.

Astronomy for School Teachers. The majority of people make their one and only contact with astronomy in the schools, and the next sections of this article will deal with astronomy in the schools. Unfortunately, very few teachers (especially at the elementary school level) have any training in astronomy, and they are therefore reluctant to teach astronomy in their classes.

There are two approaches to these teachers: one is a direct one, and the other is through provincial or local board science consultants, where such personnel exist. At the direct level, universities can offer practical astronomy courses, for credit or otherwise, in the evening or summer. They are not only accessible to teachers, but also provide a method for increasing astronomy enrolment in the university. At least two universities (Waterloo and Laurentian) have had good experience with credit *correspondence* courses, and Dr. Alan Batten has developed a very successful non-credit correspondence course offered by the British Columbia department of education.

University departments of astronomy should pursue the possibility of

produce an article or program about astronomy, the astronomer may wish to do so himself. Popularization is enjoyable, challenging, and occasionally lucrative!

Canada's champion popularizer of astronomy is surely Dr. Helen S. Hogg. Her column "With the Stars" has appeared weekly in the Toronto *Star* for 25 years (the total number of column-readers exceeds 10^6!). An outgrowth of this column is her recent book "The Stars Belong to Everyone" (Doubleday, 1976) which is destined to enjoy a wide readership for many years to come. She has appeared on numerous radio programs, and has conducted a popular series of television programs on astronomy.

Much of the success of Dr. Hogg's work is due to the fact that she has always been active in teaching and research in astronomy. The professional *astronomer*, through his position at the frontiers of astronomy, and through his daily contact with his students and colleagues, has many advantages over the professional *popularizer*.

Astronomers often have the impression that it is presumptuous of them to volunteer their product to a publishing house, magazine, radio or TV station and that, if they *did* volunteer, they would likely be turned down. This is not usually the case! Furthermore, although the preparation of a book can occupy a goodly fraction of a lifetime (unless one be a Patrick Moore or an Isaac Asimov), the preparation of an article for *Scientific American* or *Sky and Telescope* requires a much more modest outlay, and the readership and satisfaction are almost as great. Both books and articles can be more influential than the authors might expect, especially when they find their way into school libraries and classrooms.

Summary. Most astronomers are engaged in education, either because of the requirements of their job or because of their own interests, or both. The purpose of this paper is not to ask astronomers to double the time and effort they spend on education, but is to encourage all of us to be education-minded, to assure those who are that their efforts are worthwhile, to call attention to what is being done elsewhere, and to suggest a *few* new projects which are worth supporting. It is difficult to treat a broad topic like education in an article as short as this one. For more detail, more depth and even more breadth, I refer the reader to the *definitive* study of education in astronomy (Berendzen 1972), the proceedings of an international conference on education in, and history of, modern astronomy, August 30–September 1, 1971. I urge all readers to send me comments, ideas, references to interesting articles, and short articles of their own, on the subject of education in astronomy. I will endeavour to recycle this material through the *Education Notes* column – coming soon in this JOURNAL.

Acknowledgments. I am very grateful to Lydia Dotto, David DuPuy, Douglas Hube, Douglas Paul, Bill Peters and Gary Welch for their helpful comments on education in general and this manuscript in particular.

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THE TEACHING OF ASTRONOMY IN CANADIAN SCHOOLS*

BY JOHN R. PERCY
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(Received October 30, 1979)

ABSTRACT

This paper is based on one given at a meeting of astronomers and teachers at the 1979 General Assembly of the International Astronomical Union. It discusses the problems of teaching astronomy in the schools, both in Canada and elsewhere, and it presents some partial solutions to these problems. It then outlines the place of astronomy in the school curriculum in Canada. Education is a provincial responsibility in Canada and curriculum planning and implementation are often delegated to local school boards. Therefore the nature, quality and quantity of the astronomy taught vary considerably across the country.

The scope of astronomy is as wide as the universe, and its vitality is such that new advances occur almost every day. The environments of the universe attract a wide variety of scientists – and non-scientists too – for astronomy has had a tremendous impact on all aspects of civilization down through the ages. It is at once abstract and impractical, but philosophical and profound.

For centuries, astronomy was one of the pillars of a general education. Today – despite the growth of the subject – astronomy plays a minor role in our education systems. *In fact, a student in Canada can graduate without encountering astronomy at all!* No wonder the public has such difficulty in distinguishing astronomy from astrology, and observatories from planetariums. Why is astronomy so neglected in our school system?

The Problems of Teaching Astronomy. There are certain problems which seem to hamper the teaching of astronomy throughout the world. The following are some, along with possible solutions:

1 *Astronomy is abstract and of little practical importance.* This might be a good argument against teaching astronomy in a developing nation, but it is used in developed nations as well. Yet astronomy fascinates every student, and intelligent discussion of abstract topics is good mental exercise.

*Paper delivered at a one-day meeting on "The Teaching of Astronomy", sponsored by Commission 46 of the International Astronomical Union, and held in Montréal on 13 August, 1979.

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2 *Astronomy is mathematical and technical.* I hear this from almost every potential astronomy student in university (but rarely from a potential astronomy student in the schools). This view is inaccurate, of course: the subject can be taught at a non-technical level, and can be appreciated by almost every intelligent person.

3 *Teachers have no training in astronomy.* This is a real and serious problem. If teachers have no training in astronomy, they will probably not teach it unless they have to, and so the vicious circle continues. Training *is* available, through university courses (see Percy 1978b) and other courses offered by colleges, school boards and planetariums. However, the most practical solution to the training problem is *in-service training*, in the form of short courses and workshops. Books and other resource material are readily available (for instance, see Percy 1977a, 1977b) but there is an additional problem in communicating this availability to the teacher.

4 *The subject is so broad and rapidly changing.* The teacher is overwhelmed by the variety of topics with which he feels he should be familiar. Nevertheless, there is a core of simple, basic material which could form a worthwhile unit* on astronomy. Good textbooks are available to cover such material (see Percy 1976, p. 286); recent advances can be handled by maintaining a good bulletin board of press clippings.

5 *So many approaches are possible.* These seem to depend to a large extent on the prevailing philosophy of education. The following are some examples, based on units or courses which actually exist:

i) Classical, with emphasis on seasons, phases, eclipses, tides ... .
ii) Historical, with emphasis on planetary motions. An astronomy unit with this approach is often found in physics courses in high school.
iii) Practical, with emphasis on problems and projects dealing with positions and motions in the sky. The syllabus for the O-level astronomy course in Britain combines this approach with the following.
iv) Descriptive with formal observational projects.
v) Descriptive with informal observational projects. The book *The Stars Belong to Everyone* (Hogg 1976) would make an interesting textbook for this approach.

*A unit is a portion of a course (in science, for instance) on a distinct topic.

vi) Library research. The student writes a project on a topic of his choice, based on library research.
vii) Space-oriented. This approach was in vogue in the early 1960's, but is uncommon today.
viii) Interdisciplinary. An example would be the "Space and Man" course which exists in Ontario, in which the class may study any of about 20 topics related to space.
ix) Speculative, covering "gee whiz" topics such as astrology and UFO's.

Fortunately, the present philosophy of education is such that approach (iv) is the most often recommended. Textbooks exist – and are being produced – for this approach (see Percy 1976, p. 286).

6 *Practical work in astronomy is difficult to arrange.* ("The stars come out at night ... the students don't.") There are two solutions to this problem. One is to make daytime observations, such as are described in the textbooks mentioned above. The other is to provide the students with sufficient instructions to observe on their own in the evening. The monthly sky guides produced by newspapers, planetariums and the National Museum of Science and Technology are particularly useful (Percy 1978a).

7 *Astronomy teaching requires specialized, expensive equipment.* Not so! The unaided eye, perhaps supplemented by a pair of binoculars, is sufficient.

The above problems are almost universal, but there are other problems which are particularly applicable to Canada.

8 *Canada has two official languages.* Until such time as we are all fluently bilingual, there is no easy solution to this problem, so we must ensure that the necessary resource material, and channels of communication, are available in both official languages.

9 *Canada is geographically dispersed.* This limits the practical ability of teachers and scientists to meet together easily and cheaply for conferences and workshops (in contrast to Britain or The Netherlands, for instance). Consequently, provincial science teachers' associations can play an important role, as can astronomers and planetarium personnel at the local level.

10 *Education is a provincial responsibility.* Curriculum varies from province to province and – largely as a result of the liberalization of educa-

tion – it can vary from school to school! [There is not even consistency of grade structure from province to province; in most provinces students enter university after grade 12, but in Ontario students enter after grade 13 and in Quebec students enter CEGEP* after grade 11, then enter second-year university after two years of CEGEP.] Until recently, there was a standard provincial curriculum in each of the 15 to 20 subject areas. Now, to illustrate the variation of curriculum *within* a province, there are presently 184 recognized courses – including dozens in some subject areas – in Ontario grade 13 alone! This variety makes it difficult to prepare textbooks and resource material which can be used widely. Fortunately, the pendulum is now swinging in the direction of greater uniformity. One can find a common denominator among those astronomy units which *are* offered, and one can prepare resource material for them.

The ten preceding problems lead to an even larger problem: lack of confidence on the part of the teacher. Motivation and the best of intentions are hardly enough to get the teachers over the hurdle of unfamiliar material. Where can they turn for help?

The ministry of education, which prescribes the curriculum, provides helpful advice in some provinces but not in others. Science teachers' associations† exist in most provinces, and provide an important source of education and communication through their meetings and newsletters. A Canadian association of science teachers exists but is not very active (it is difficult to operate any such national organization in Canada), and a Canadian branch of the American Association of Physics Teachers has recently been formed. At the level of the local board of education, there are often consultants or co-ordinators for science. These people may have considerable influence over which optional topics (such as astronomy) are or are not taught. Where these people have an interest and knowledge in astronomy, the teaching of astronomy is in good hands. Otherwise, the teacher must fend for himself.

An effective means of teacher education is in-service training in the form of short courses or workshops. These may be given by professional astronomers, planetarium or museum personnel, consultants or co-ordinators, or knowledgeable teachers. They may take place after school, on weekends, or on "professional activity (P.A.) days" (as they are called in Ontario). P.A. days have a bad reputation among a segment of the public,

*Collège d'enseignement général et professionel.

†The author has a list of such associations, and will send a copy of this list to interested readers.

but not among those of us who see how most teachers use them. In-service training gives the teacher practical advice on content, methodology and resources, and some confidence that he can use these when he gets back to his classroom on Monday morning. In-service training is not a magic solution, of course. There are many other areas – some perceived as being more important – which compete for in-service training time.

As well as human resources, teachers have access to other resources in the form of textbooks, articles, audio-visual aids and equipment. Some of these have been described in this JOURNAL (Percy 1977a, 1977b, 1978a) and in subsequent columns in its bi-monthly "Education Notes" section.

The Astronomy Which Is Taught. The rest of this paper examines the specific topics which may be taught as part of an astronomy unit or course. Astronomy is taught as part of science or geography courses. It is rarely a compulsory topic, but must compete (often unfavourably) with more familiar and relevant topics. Furthermore, the content of the astronomy unit may not be specified, but may be left to local preference. In spite of all this, there is a certain consistency to the material which is taught at various grade levels, as follows:

K–5: Simple concepts of light and shadows, night and day, the changing seasons, earth, moon, sun, planets and stars.

6–8: Simple observational studies of the sky and a description of the planets and stars. Myths and legends about the sky. (This is the most common level at which a substantial and often compulsory unit is taught.) A visit may be made to the local planetarium or observatory, and this may act as a strong incentive and focus for teaching some astronomy in their classroom.

9–10: A substantial unit in place of (or very occasionally as well as) the unit in grade 6–8.

11–12: An optional (usually) unit on gravity and planetary motion, as part of a physics course, and a compulsory (usually) unit on the place of the earth in the universe, as part of a geography course.

In addition, it is usually possible for a school to receive special permission to teach a course in astronomy, either as a distinct course or under the rubric of an already-approved course (such as "Space and Man" in Ontario). A few teachers make use of this possibility in order to teach a comprehensive course in general astronomy.

An example of a "substantial unit of astronomy" is the following, which was recently introduced by the Ontario Ministry of Education. It is part of a grade 7 or 8 science course, it is the only major unit of astronomy in the

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science curriculum, and it is optional. The topics with asterisks are obligatory (if the unit is taught); the others are suggested. The numbers in parentheses are the number of 40-minute periods to be spent on the topic. The "capsule comments" following each topic are *my own* comments and suggestions.

1 *Historical Development (1)*. It is impossible for young students to appreciate the contributions of any one of Copernicus, Tycho, Kepler, Galileo and Newton in one period! An alternative would be to combine systematic observations of daily and seasonal motions with a discussion of the place of astronomy in ancient civilizations and to take some time to do so.

2 *Orbital Motion (1)*. Too often, the students simply memorize the orbital elements of the planets. Perhaps it would be better just to look at the order and regularities which exist – or to build a moving model of the solar system in the playground.

3 *The Earth (1)**. Again, the emphasis is too often on numbers. It might be more profitable to discuss the scale of the earth, and the structure and evolution of the earth in comparison with other planets.

4 *The Moon (2)**. Here, some observations are possible. Traditionally, the emphasis is on phases, eclipses and tides, but a discussion of the lunar surface and of space exploration should not be overlooked.

5 *The Planets (3)**. Observations of planetary motion – and perhaps some telescopic observations – are possible. A discussion of the surfaces and atmospheres of the planets, especially in comparison with earth, would be interesting. Avoid rote memorization of numbers.

6 *The Sun (2)**. The unit specifies five subtopics: surface features (which are interesting but not desperately important), the interior (which should be discussed briefly), effects on the earth (worth discussing!), eclipses (which can probably be ignored unless one is about to occur) and life cycle (which is definitely worth discussing in a general way).

7 *The Stars (2)**. The unit specifies everything from star and constellation names to the nature and evolution of stars, and to unusual stars such as pulsars, binaries and variables. Surely some practical constellation study should be obligatory. Some knowledge of the nature and evolution of the stars would also be worthwhile, but a discussion of the more exotic objects could probably be omitted, interesting though it might be.

8 *Other Celestial Bodies (1)*. This includes everything from comets to galaxies.

9 *Astronomical Instruments (1)*. At the *end* of the unit? Still, it's important for the student to know how astronomy is done and why it has to be done that way.

Note that this unit, like many similar ones, covers virtually every topic in astronomy – to be covered in 14 periods! Obviously the teacher must be selective.

The preceding is an example of the topics in astronomy which *may* be taught in Canadian schools. Due to local choice, others may be taught – or none at all.

Because of the decentralized control of the school curriculum in Canada, any effort to improve the teaching of astronomy must be made at the provincial level or lower. National organizations such as the Canadian Astronomical Society and the Royal Astronomical Society of Canada can have some influence by promoting and publicizing astronomy, by producing resource material (a resource "package" for a standard unit on astronomy might be useful) and by communicating their concern to provincial ministries of education. In the long run, however, local astronomers *must* become involved, by advising and assisting local teachers and by acting as a link with national organizations. Astronomy is an important and exciting science; it deserves a more secure place in our schools.

Acknowledgements. I wish to thank Douglas Paul and the many other educators across Canada who sent me information on which this paper is based.

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EDUCATION NOTES

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EDUCATIONAL MATERIAL IN ASTRONOMY PRODUCED AND DISTRIBUTED BY CANADIAN OBSERVATORIES, MUSEUMS AND PLANETARIUMS

The following list is based on the replies to a questionnaire circulated late in 1977. If there are any omissions, please notify the undersigned. The items marked (+) are free of charge for single copies. It is hoped that the publication of this list will result in greater awareness, co-ordination and exchange of material between the various institutions.

David Dunlap Observatory, Richmond Hill, Ontario L4C 4Y6. Pamphlet: Time By The Stars ($0.05). Pamphlets (+): The David Dunlap Observatory; The University of Toronto Telescope in Chile; UFO's. The Observatory also distributes some of the pamphlets produced by the National Museum of Science and Technology.

Dominion Astrophysical Observatory, Victoria, British Columbia V8X 3X3. Fifty-six page booklet (+) describing the Observatory, its work and some related topics in astronomy. Booklet (+) of twelve star maps.

Dominion Radio Astrophysical Observatory, Penticton, British Columbia V2A 6K3. Pamphlet (+) describing the Observatory and its work.

National Museum of Science and Technology, 1867 St. Laurent Blvd., Ottawa, Ontario K1A 0M8. Set of sixteen four-page folders (+) in English or French on a variety of topics in basic astronomy: the sun, moon, Mars, etc. Set of four star maps (+). Four-page monthly sky sheet (+).

National Research Council, Public Information Branch, Ottawa, Ontario K1A 0R6. Pamphlets (+): Algonquin Radio Observatory; Herzberg Institute of Astrophysics; The Canada-France-Hawaii Telescope.

Calgary Centennial Planetarium, Mewata Park, Calgary, Alberta T2P 2M5. Quarterly magazine ($0.50 each) containing articles, star maps and listings of sky phenomena. Book and gift store.

Dow Planetarium, 1000 St. James St. W., Montreal, Quebec H3C 1G7. Book and gift store.

H.R. MacMillan Planetarium, 1100 Chestnut St., Vancouver, British Columbia V6J 3J9. Seven pamphlets (+) of teaching notes in space science, two or three pages each: The Celestial Sphere; Meteors, Comets and Asteroids; The Observer's Handbook; Solar and Lunar Eclipses: Telescopes; Building a Telescope; Astronomical Terminology. NASA pamphlets and photos as and when available. Book and gift store (catalogue available).

Manitoba Planetarium, 190 Rupert Ave., Winnipeg, Manitoba R3B 0N2. Astronomy fact sheets (+) providing background information for teachers, senior students and the public: about a dozen topics, one to six pages each. Set (+) of six star maps. Forty-four page book ($3.95) by W.E. Webster and G.E. Lammers: "Prelude to Life", dealing with the origin of the solar system, earth and life. Book and gift store.

McLaughlin Planetarium, 100 Queen's Park, Toronto, Ontario M5S 2C6. Pamphlets (+): Acquiring a Telescope; Reading List on Astronomy. Book ($0.50): "The McLaughlin Planetarium", dealing with planetariums and various topics in astronomy. Book and gift store (catalogue available).

Queen Elizabeth Planetarium, 10th Floor, CN Tower, Edmonton, Alberta T5J 0K1. An excellent set of sixty-page information packages ($1.25 each) on astronomical topics, including activities, vocabulary and answers to typical student questions: The Constellations; The Solar System; Celestial Motions; The Sun and Stars; Extraterrestrial Life. Monthly sky chart and calendar (+). Book and gift store (catalogue available).

Seneca College Planetarium, 1750 Finch Ave. E., Willowdale, Ontario M2N 5T7. Teacher's guide (+) to accompany school programs.

JOHN R. PERCY

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Readily Observable Phenomena ASTRONOMY

Dave Berryman

The following article could be used in several ways, one of which is a student assignment. Toward the end of your Grade 9 astronomy unit, have students seek answers or *reasons* for the "readily observable phenomena." All the phenomena stated here are readily observable in low-power equipment (most are naked-eye observations). To conserve space in the newsletter, I am listing the phenomena without sufficient space for the student to state the "reason" for each. Retype them to suit your needs. If I have missed any phenomena, please let me know. I did not include satellites, tides and auroras.

The Moon

1. The moon rises in the east and sets in the west.
2. The moon appears as a flat circular disc.
3. The moon appears to travel across the sky a little slower than the sun.
4. The moon's disc is composed of dark and light patches when viewed with the naked eye. These patches look like a face to some people.
5. The disc of the moon is displayed in shapes ranging from a thin crescent, through full, and back to crescent over the course of three or so weeks.
6. There are a few consecutive days of the month in which the moon does not appear to rise.
7. The position of the moon in relation to the stars appears to shift to the east (right to left). This shift is about 12 moon diameters per day.
8. The moon is not as bright as the sun.
9. There is no dectectable warmth from the moon.
10. The size of the sun's disc is apparently the same size as the moon's disc.
11. The size of the moon's disc appears larger when the moon is near the horizon.
12. On some occasions when the moon is full, a shadow or darkness slowly covers the face of the moon. The edge of this shadow is curved.
13. The same face of the moon is always seen from Earth.
14. Telescopic inspection of the moon reveals three distinct features: bright mountainous regions, dark flat regions, and craters.

The Stars and Planets

1. At night, the stars appear as tiny shimmering points of light.
2. Some stars appear brighter than others.
3. The stars have different colors ranging from light blue, through white, to yellow and red. These colors are barely detectable.

4. The stars appear to be the same distance away from the observer.
5. The stars do not appear to change their positions in relation to each other. They appear fixed.
6. The stars appear as very tiny points even when magnified with a telescope or binoculars.
7. Magnification of the sky reveals more and more stars.
8. Some stars do not appear to twinkle in the normal way.
9. These peculiar stars alter their positions in relation to the other stars. It is because of this wandering that the word "planets" is used to identify them (planet=wanderer).
10. The planets move very slowly to the east (right to left) in relation to the fixed stars.
11. On some occasions, some planets appear to stop their eastward motion and begin a westward motion relative to the background stars.
12. Five planets are fairly easily found. Saturn, Jupiter, Mars, and Venus are easy to locate. The fifth, Mercury, can be seen only at sunrise or sunset at certain times of the year.
13. Magnification of these planets reveals a circular disc (except Venus).
14. The brightest of all the heavenly bodies is Venus (with the exception of the sun and moon).
15. Moderate magnification of Venus reveals that crescent "moonlike" phases occur. Venus is brightest when it appears as a crescent.
16. The planets Saturn, Jupiter, and Mars never appear as crescents.
17. Magnification of Saturn reveals ringlike structures.
18. Magnification of Jupiter reveals bands across its disc and four smaller bodies near the planet that change their positions from night to night.
19. The planet Mars has a distinctive reddish-colored disc.
20. Stars in the northern sky seem to circle a central point.
21. Stars in the northern sky appear to move counter-clockwise.
22. The planets take the same (or nearly the same) path across the night sky as the sun and moon do. The planets do not appear in the northern sky.
23. On some occasions, a star may be seen to move rapidly across the sky as if it were falling. This is called a "meteor."
24. The stars form various recognizable patterns (constellations).
25. There exists a narrow hazy path that travels across the sky. It is called the "Milky Way."
26. Other small misty patches of light can be seen with some difficulty—more easily seen out of the "corner" of your eye.

The Sun

1. The sun rises in the east and appears to cross the sky from left to right. It then sets in the west.
2. The sun appears as a flat circular disc.
3. The sun is the brightest object in the sky.
4. The sun gives off heat.
5. The sun gives off some kind of energy that causes skin to tan.
6. The sun has spots.
7. The spots on the sun are more numerous at some times than they are at others.
8. The sun spots appear to travel across the face of the sun's disc.
9. The sun rises higher in the sky in the summer than it does in the winter.
10. The sun's color is white with perhaps a touch of yellow.
11. The point in the east where the sun rises shifts more and more to the north with the approach of summer.
12. On rare occasions, part or all of the sun's disc is blackened for several minutes.
13. When the sun's disc is totally blackened, a fairly bright and irregularly shaped corona (glow) radiates from the edges of the disc.
14. When the sun's disc is totally blackened, flares and arches of bright material can be seen rising from the edge of the disc.

The Mysterious Satellites of Saturn

Dr. C. Madhosingh
Britannia School, Vancouver

For the first time mankind has had the opportunity to study middle sized "moons", as the Voyagers swept by Saturn. We have examined the 2 small satellites of Mars and some planet-sized ones around Jupiter.
Now the space probes have unleashed a massive examination of the Saturnian Satellites and their interaction with the extra-terrestrial surroundings.

TITAN DETHRONED

We have found that Saturn has at least 17 satellites and there may be a few more. Titan is the largest in the system and second to Jupiter's Ganymede. Textbooks claim that Titan is the largest known "moon" but the Voyagers have reported that its atmosphere is much deeper than had been previouly predicted.

NEW SATELLITES

Textbooks have also named 9 discernible satellites. Voyager scientists at the Jet Propulsion Laboratory and ground-based astronomers have discovered 8 more. One satellite was found near the edge of the A-ring; it may define the ring's boundary. Two others appear to bracket the narrow F-ring, probably holding its icy particles, by gravitational attraction, within the ring's narrow boundaries. Another one shares the orbit of the satellite Dione, while two others orbit Saturn, one in front of and the other behind Tethys, another Satellite. Two others share the same orbit and one is overtaking the other, these are called the co-orbital satellites.

OTHER SATELLITES

The probes sent back information on the other Satellites. Mimas, Enceladus, Tethys, Dione and Rhea are approximately spherical in shape and may be composed mostly of ice. Tethys seem to be ice while Dione shows a density which suggests that it is 40 per cent rock.

MIMAS

Mimas has an impact crater covering more than one fourth of the diameter of the moon. Nowhere else have we seen such a disproportionately large crater. Had this crater been any larger, it would probably have shattered Mimas into fragments. The crater has a raised rim and a central peak. Other craters between 15 and 45 km. in diameter are scattered across the surface. The other side of Mimas is also heavily cratered, with a long narrow trench about 5 km wide. The surface appears to be covered with a light, powdery snow.

ENCELADUS

Enceladus was not closely observed by Voyager 1 and pictures showed that it was a smooth snowy moon. This suggests that internal processes may have erased any major surface craters and mountains. Voyager 2 pictures revealed that this moon has smooth fractures, ridges and a number of scattered smaller craters. There may be gigantic snow fountains gushing out from under the icy surface. Gravitational forces may be pulling and pushing at Enceladus causing it to heat up from within. This moon is providing us with new information on how nature behaves in outer space.

TETHYS

Tethys has a heavily cratered half which always faces Saturn, analogous to our moon's half which always faces the Earth. It has a valley about 750 km (500 miles) long and 60 km (40 miles) wide. The craters appear to be the result of impacts and the valley may be a major fracture.

DIONE

Dion exhibits two distinctly different atmospheres. It shows bright radiating patterns which may be rays of debris thrown out of impact craters. Other areas reflect much light and may be higher ridges and plateaus. Dione's other hemisphere also shows several impact craters—the record of cosmic collisions. The largest crater is less than 100 km (60 miles) and contains a characteristic central peak. Winding valleys appear at the poles and these may be the result of crustal fracturing in the icy crust.

RHEA

Rhea displays wall-to-wall cratering and appears to be Saturn's most heavily cratered moon. The largest crater measured, by the impact of cosmic debris, is about 300 km (190 miles) in diameter. These ancient impact craters closely resemble those on our Moon and peaks which we believe are formed by the rebound of the floor during the explosive formation of the crater. Some craters are very old and others are damaged by later impacts. Several have sharp rims and appear relatively young while others are very shallow and have subdued rims. White areas on the edges of the craters appear to be fresh ice exposed on steep slopes. Others show the ice near fractured regions and this can imply that white volatiles may be escaping from the interior of Rhea.

TITAN

Titan is completely covered with a dense atmosphere. We are not able to study its surface.

HYPERION

Hyperion was the satellite that was supposed to be a very uninteresting object. Voyager 1 saw no features on it due to its distance. When Voyager 2 sent back its first picture of Hyperion it looked like a giant peanut and all of us at the Jet Propulsion Laboratory started to take notice. In all 12 pictures were taken of the moon and as the spacecraft gained altitude, we began to see a more or less par-

tially spherical object. It started to become an extra-ordinarily interesting object as it gradually assumed the appearance of a giant hamburger patty with a part bitten off. A large crater had one half of its walls broken down and the entire surface appeared to be very old with a gray coloured frost covering it. Hyperion is about 300 km long and 200 km wide. According to the known laws of physics, the long axis of the satellite should be pointing to the planet but Hyperion defies the laws! Its long axis is not aligned as is expected. This could imply that at some time in the distant past this moon experienced a colossal collision and was knocked out of its orbit and is gradually regaining its equilibrium position.

IAPETUS

Iapetus has always been a mysterious object to earthlings. When we look at it through a telescope at times it appears to be dark while at other times it is very bright. Now the Voyagers have revealed its secret. About 1/3 of its leading hemisphere is covered with some very, very dark material, much darker than any other naturally occurring material known to exist. We have absolutely no idea of the nature of this material. This satellite has a density of about 1.1 so it may consist of 7 per cent rock and 93 per cent ice.

PHOEBE

Phoebe is the most distant of Saturn's moons. Voyager 1 did not pass near to it and when Voyager 2 did approach it, the scan platform on board was still malfunctioning. However, some observations did take place concerning Phoebe. Phoebe is a very dark object, reflecting only about 5 per cent of the light falling on it. It takes about 9 hours to make one rotation and it is travelling around Saturn in a direction opposite to that of the other moons. It is quite probable that Phoebe did not form near Saturn but was passing near the system and was captured and placed in an orbit around Saturn.

Star Stuff

Jupiter Watch Continues—Jupiter Revealed

Dr. Chandra Madhosingh

Voyager invades Jupiter

Jupiter's curious ring of particles, its powerful magnetic field, and the Galilean satellites Europa, Ganymede, Callisto, and Io with its active volcanoes, were among the key scientific targets for the two Voyager spacecraft this year. *Voyager 2*, the twin robot of *Voyager 1*, which made several new discoveries in March, kept a keen surveillance on the Jovian system last July. On their way to Jupiter, the two spacecraft rolled and twisted through a series of near encounters with the exciting and enigmatic moons of Jupiter, which were first seen by Galileo in 1610 as pinpoints in the sky.

The Jet Propulsion Laboratory at Pasadena, California was a beehive of activity immersed in the processes of discovery and sciencing. Teams of scientists are still involved in studying imaging science, radio science, plasma waves, infra-red radiometry, ultra-violet spectroscopy, photopolarimetry, planetary radio astronomy, magnetic fields, low-energy charged particles, plasma science, and cosmic rays.

Scientists are only just beginning to understand some of the physical, geological, and atmospheric processes that are ongoing in the Jovian System.

Volcanoes

The discovery of eight active volcanoes on the "moon," Io, was probably the most exciting surprise and may turn out to have the greatest far-reaching effects. It may be that the Ionian activity is affecting the entire Jovian system. Io appears to be the source of matter that pervades throughout the lines of force of Jupiter. Sulphur, oxygen, and sodium particles are ejected out of the eruptions and are strewn out to the outer edge of Jupiter's magneric field. Some of these atoms were also found inside Io's orbit, where they appear to be travelling at speeds of up to 18,000 miles per second!

Galilean satellites

Voyager measured the temperature of a large hot spot on Io, which seems to be associated with a volcanic feature. The surrounding terrain has a temperature of -138° C (-216° F) and the hot spot's temperature is about 20° C (68° F). The hot spot seems to be a lava lake, but the surface may not be molten. "Islands" on the lake itself are composed of blocky plastic lava called *epimagma*, while the lake itself is composed of thin fluid material called *pyromagma*. Materials from the volcanoes extend up to heights of 250 km (155 miles) and are being ejected at rates of 3600 km/hr. (2200 mph). Mount Etna, one of Earth's most explosive volcanoes, ejects materials at only 180 km/hr (112 mph). As Io orbits Jupiter, it is being yanked back and forth by the large moons and an electromagnetic current, of about five million amperes, is contributing to another motion that causes it to move up and down like a yo-yo.

Voyager also discovered that both Europa and Ganymede are covered with layers of ice, but the geological processes of the moons are completely different. Europa has long, sinuous, disorganized cracks on the ice. Under certain conditions on Earth, warm ice becomes plastic and shows similar features. When we looked at the dark lines near the terminator, we could not see any bright surface edges and this suggests that the cracks may be very shallow. One area on Europa was photographed, and this showed a region where several fractures do cross, 10 to 12 km wide. This may be an older region where there appear to be a few craters. Close by, a unique, highly reflective white winding line was seen. Near the North Pole are a few low, randomly scattered mountains less than 4 km high. Ganymede shows contortions and twisting patterns with several block faults and craters. Some areas appear flat and smooth, while others show abrupt changes.

Jovian rings

As *Voyager* flew past, it swung into the dark side of Jupiter to re-establish radio contact with Earth. It snapped pictures as it probed the planet's dark side, including a 150-photo sequence of the volcanoes of Io. Some of the color photos revealed an unexpec-

This image of Europa, smallest of Jupiter's four Galilean satellites, was acquired by Voyager 2 on July 9, 1979, from a range of 241,000 kilometres (150,600 miles). Europa, the brightest of the Galilean satellites, has a density slightly less than Io, suggesting it has a substantial quantity of water. Scientists previously speculated that the water must have cooled from the interior and formed a mantle of ice perhaps 100 kilometres thick. The complex patterns on its surface suggest that the icy surface was fractured, and that the cracks filled with dark material from below. Very few impact craters are visible on the surface, suggesting that active processes on the surface are still modifying Europa. The tectonic pattern seen on its surface differs drastically from the fault systems seen on Ganymede where pieces of the crust have moved relative to each other. On Europa, the crust evidently fractures, but the pieces remain in roughly their original position.

tedly sharp image of the ring, which has a high reflectivity.

There seems to be some structure in the rings of Jupiter. There is a narrow outer ring, about 6000 km wide and an inner ring of thinner matter, which stretches down to touch the clouds of Jupiter. The ring's outer edge is about 80,000 miles from the centre of the planet and no more than 18.5 miles thick. Super bolts of lightning and auroras were clearly detected in the darkness, when pictures of the rings were photographed.

Green light to Saturn

Voyager 2 pulled away from Jupiter but continued to transmit information to us for another 12 days as it swooped through Jupiter's magnetic tail. *Voyager 1* will rendezvous with Saturn on November 8, 1980, and *Voyager 2* is scheduled for contact with that system in August 1981 and a 1985 cruise by Uranus.

How To See the Edge of Night as the World Turns

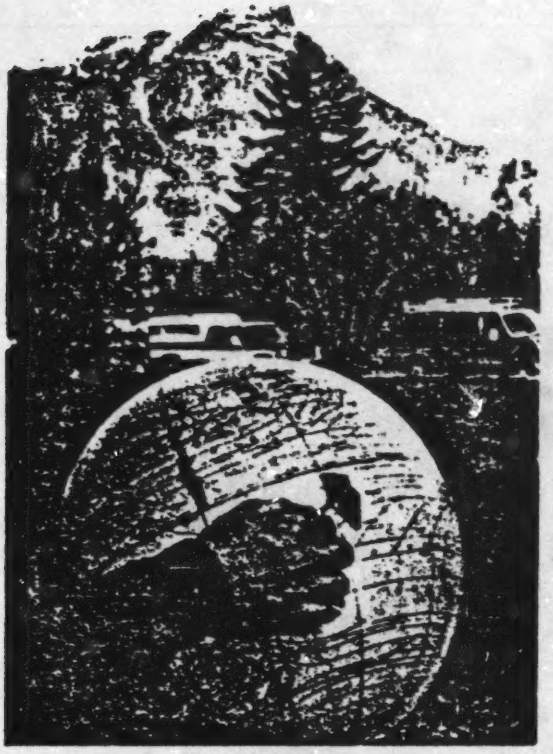
Allan Wooton

Some time ago, I was reading an article entitled, "A Universal Sundial" in the book *The Amateur Scientist* by C.L. Strong, Simon and Schuster, New York, 1960. I found the article really fascinating and have enjoyed using a universal sundial ever since, especially at equinoxes or at solstices. There are other references to this type of universal sundial, but it is worth while reading C.L. Strong's article for the background information presented there. Here, though, is a brief explanation of how to set up a universal sundial.

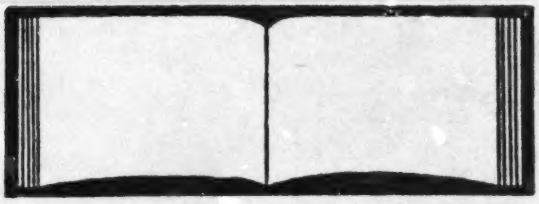
To make the sundial, you need a globe. The object is to align the globe in exactly the same manner as the earth itself is aligned so that the sun's light strikes the globe at exactly the same angle as it hits the earth. To do this you need a globe that can be set with its axis at different angles. Many globes are set in stands that hold their axes at 23½° to the horizontal; if this is the case, it is necessary to remove the globe from the stand and set it in some sort of support like a flower pot or large beaker. Once this is done it is possible to set the globe so that the observer's locality is up. To do this, you find your location on the globe and put this to the top. For example, if you live in downtown Hagensborg, you put the globe so that Hagensborg is on top. (What, you can't find Hagensborg on your globe?) Next, you turn the globe so that the north pole of the axis points to true north, and with that, the globe should be lined up in just the same manner as the earth itself is.

The globe is aligned so that Hagensborg is on top and the N. pole of the axis points north.

The sunlight landing on the globe should be striking the globe at just the same angle as sunlight striking the earth; the part of the globe in shadow should also be the part of the earth that is in darkness. You can see where on the earth it is midnight and where it is noon. By making a little triangular stand, you can find where on earth it is that the sun is directly overhead, and you can see how much of the poles are lighted or in darkness. And as the world turns, you can see the edge of night move from east to west.



The little triangular stand is made of cardboard. It is being held so that it casts the smallest shadow on the globe. The sun should be directly above the part of the earth where the stand is.



Book Reviews

Allan Wooton

Some publications which are of interest to both students and teachers are:

Astronomy published monthly by AstroMedia Corp. 411 E. Mason Street, P.O. Box 92788 Milwaukee, WI 53202. $18 per year.

Science News published weekly by Science Service Inc., 1719 N. Street, N.W. Washington, DC 20036. $18.50 per year.

The Observer's Handbook published annually by the Royal Astronomical Society of Canada, 124 Merton Street, Toronto, ON M4S 2Z2.

Astronomy has many varied and interesting articles, which tend to be written at a less difficult level than articles in a magazine like *Sky and Telescope*. The disadvantage is that they also have tended to be somewhat vague in detail, treating popular astronomy topics with lots of artwork and some lack of substance. Recently this seems to have changed and as well there are really worth-while articles on topics like choosing telescopes, types of telescopes, astrophotography, the month's stars and planets, and recent news in astronomy as well as excellent photos (the recent Jupiter and Saturn photos are spectacular). I have found that this magazine is one students read and enjoy, and I really recommend it as one for a science classroom.

Science News is a weekly newspaper of science. Each week there is a feature article (or articles) as well as shorter sections on topics of interest. It only takes about half an hour to read an issue, so I find this magazine serves as a quick way to keep up with some of the things that are being done in science. Like *Astronomy*, *Science News* is a magazine students can read, and I have found it a worthwhile exercise to assign Grade 11 students to write summaries of articles from these magazines.

The 1980 issue of *The Observer's Handbook* should be out soon. It comes automatically if you are a member of the Royal Astronomical Society (a worth-while organization to belong to), but it can be purchased at the Vancouver Planetarium (1100 Chestnut Street, Vancouver, BC V6J 3J9). This handbook is filled with information about stars, the planets, occultations, the sky month by month, and many other tables and pieces of information useful to people interested in stars.

COLD WEATHER HINTS

To be comfortable outside, it is especially important to keep your head, hands and feet warm. A knitted hat and scarf are minimum head wear. A coat with a hood to provide additional protection is a big help, especially if it is windy. Gloves or mitts should be wind and waterproof with a heavy pile lining. I prefer to wear a thin tight pair of silk or cotton gloves inside a loose fitting pair of heavy mitts. Then I can easily slip off the awkward outer mitts, and adjust the cold metal knobs on my telescope and cameras, protected by the thinner pair. Boots also should be well lined, with room for two or more layers of heavy socks. (Ski-doo or muck-luk style boots work well). Thermal underwear under heavy trousers and several loose layers of knitted and woolen clothing should provide enough body warmth, even under a light coat, provided that it is wind proof. Down filled clothing, and ski-doo suits are very comfortable, but a considerable expense if you don't plan to get much more use out of them.

The charcoal, or lighter fluid powered handwarmers sold by sporting goods stores are an inexpensive way to warm up finger tips and cold spots.

Cars should be winterized. This means a thorough ignition tune-up, the installation of a cold weather thermostat, a change to lighter oil (10-30 multigrade, for example) and the addition of the appropriate antifreeze to the radiator, gas tank and window washer reservoirs. These antifreezes are available at all Manitoba service stations. Snow tires are not essential if you stay on the main paved routes; however, your tires must be in good shape.

At low temperatures the insides of your car windows may steam or frost up. This can be prevented by applying frost shields to the side windows, especially along the line of sight to the side mirror, and to the rear window if it lacks an electric defroster. A block heater is often a big help. Most roadside motels provide outlets for these heaters. Always carry lots of warm sleeping bags or blankets. It is much safer to stay with a stranded car, and use the bags or blankets to keep warm until help arrives, than it is to walk for assistance.

Some cameras and telescopes seize up completely at low temperatures. If you have any doubts about your equipment, have a service man adjust and lubricate it to work at low temperatures. Telescopes should be lubricated with low temperature grease. If the controls on your scope, camera or binoculars become stiff with the cold, it is likely that the grease has thickened. Don't force the control, move it gradually with gentle, firm pressure. Cameras should be wound gently, a sudden jerk may crack the film when it is brittle with cold.

A carelessly directed breath will often coat a cold eyepiece or camera lens with a thin layer of moisture or ice. The lens must be warmed indoors to remove ice. Moisture can be wiped away with a piece of lens tissue. I usually keep a spare telescope eyepiece in a warm inner pocket, just in case I accidently frost one.

If you bring a cold camera or instrument indoors it will promptly frost up as a heavy layer of moisture from the warm, indoor air condenses on its surface. To avoid this, securely wrap the instrument in a plastic bag, or in a sheet of plastic before bringing it in. The moisture will condense harmlessly on the plastic. Unwrap the instrument when it has warmed to room temperature.

Remember, get all your equipment fitted together and working well in advance. That old standby, masking tape, just doesn't hold when it's cold out, [illegible]ar tape isn't very good, and elastics lose their snap. Batteries also give out at low temperatures. Your car battery must be in new condition. Have it tested. I carry spare camera and light meter batteries in a warm pocket. The problem with batteries is that they only put out a fraction of their power when cold. Make sure you have lots of extra battery capacity to keep your equipment going.

Manitoba is a beautiful province during the winter. The crisp, snowy landscape, and the clear skies make living here a real pleasure. With the few precautions mentioned, which we Manitobans take as a matter of course, you too can share the pleasure that we take in winter travel and activities, and enjoy the eclipse to the fullest.

—Bill Peters, Producer, Manitoba Planetarium
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THE SKY FOR MAY 1982

Last month, I discussed one of the areas in which amateur astronomers can make a significant contribution to astronomical research. There is another important contribution which amateurs can make, not directly related to astronomical *research*, and that is in astronomical *education*.

The teaching of astronomy in the schools is spotty, as I have recently pointed out (*Journal of the Royal Astronomical Society of Canada*, 74, 81 (1980)). In fact, a student can graduate without encountering astronomy at all! Outside of and beyond school, the public may encounter astronomy on TV, in the papers, at planetariums or at observatories. Despite the efforts of astronomy writers, planetariums and observatories, there is still much to be done – and many opportunities – in astronomical education for the public.

Amateur astronomers, individually and in groups, can make a tremendous contribution here. Many already do, and their efforts should be recognized and applauded. Individuals provide instruction for Scout and Guide badges, for schools and camps, and informally in their own back yards. Groups organize astronomy programs, in libraries, for instance, and "star nights" in the parks. Groups with fixed observatories open these to the public on a regular basis.

May is a good month for such programs, since Jupiter and Saturn are well placed for observing. The moon is also well placed around the beginning and end of the month. In recent years, there has been a movement to organize an annual "Astronomy Day" in North America (and elsewhere) sometime in May. Judging by past success, this event deserves to be an annual one.

The Sun—During May, the sun's R.A. increases from 2 h 32 m to 4 h 38 m and its Decl. changes from +14°55′ to +21°59′. The equation of time changes from +2 m 54 s to +2 m 26 s.

The Moon—On May 1.0, the age of the moon is 7.1 d. The sun's selenographic colongitude is 1.1° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on May 3 (8°) and May 31 (7°) and minimum (east limb exposed) on May 18 (8°). The libration in latitude is maximum (north limb exposed) on May 20 (7°) and minimum (south limb exposed) on May 5 (7°).

Mercury on the 1st is in R.A. 3 h 46 m, Decl. +22°12′, and on the 15th is in R.A. 4 h 48 m, Decl. +24°29′. Greatest elongation east (21°) occurs on the 9th. This elongation is favourable (for northern observers) due to the steep angle of the ecliptic to the horizon; the greatest elongation (21°), however, is considerably less than the maximum possible value (28°). The planet thus appears low in the west at sunset, for the first half of the month. By the end of the month it is in inferior conjunction.

Venus on the 1st is in R.A. 23 h 47 m, Decl. −2°35′, and on the 15th it is in R.A. 0 h 46 m, Decl. +3°02′, mag. −3.6, and transits at 9 h 17 m. It rises about 1¼ hours before the sun and is very low in the southeast at sunrise.

Mars on the 15th is in R.A. 12 h 04 m, Decl. +0°56′, mag. −0.4, and transits at 20 h 31 m. In Virgo, it is high in the south-east at sunset, and sets well before sunrise.

Jupiter on the 15th is in R.A. 14 h 06 m, Decl. −11°13′, mag. −2.0, and transits at 22 h 32 m. In Virgo, it is in the south-east at sunset, and sets about an hour before sunrise.

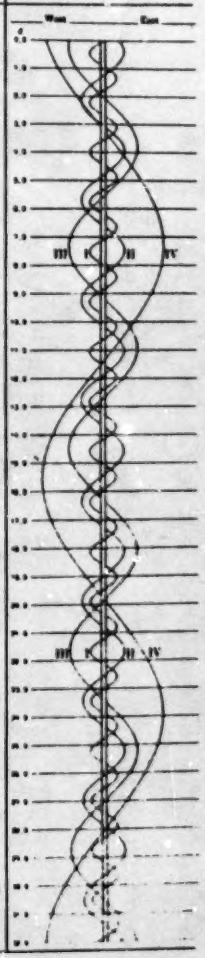
Saturn on the 15th is in R.A. 13 h 05 m, Decl. −3°58′, mag. +0.7, and transits at 21 h 32 m. In Virgo near Spica, it is well up in the south-east at sunset, and sets an hour or two before sunrise.

Uranus on the 15th is in R.A. 16 h 04 m, Decl. −20°36′, mag. +5.8, and transits at 0 h 34 m. On May 24, it is at opposition, at a distance of 17.867 astronomical units.

Neptune on the 15th is in R.A. 17 h 45 m, Dec. −22°05′, mag. +7.7, and transits at 2 h 15 m.

1982	d	h m	MAY UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
				h m	
Sat.	1		Mercury at greatest hel. lat. N.	11 50	
Sun.	2				
Mon.	3				
Tues.	4	05	Mars 3° S. of Moon	8 40	
		20	η Aquarid meteors		
Wed.	5	13	Saturn 3° S. of Moon		
Thur.	6	21	Jupiter 4° S. of Moon		
Fri.	7			5 30	
Sat.	8	00 45	☉ Full Moon		
Sun.	9	00	Mercury greatest elong. E. (21°)		
		07	Uranus 3° S. of Moon		
Mon.	10	12	Ceres at opposition	2 20	
		14	Mercury 8° N. of Aldebaran		
Tues.	11	08	Neptune 0.3° S. of Moon; occ'n[1]		
		15	Moon at apogee (405,600 km)		
Wed.	12				
Thur.	13	05	Mars stationary	1 10	
Fri.	14				
Sat.	15			20 00	
Sun.	16	05 11	☾ Last Quarter		
Mon.	17				
Tues.	18			16 50	
Wed.	19		Venus at aphelion		
Thur.	20	02	Venus 3° N. of Moon		
Fri.	21	10	Mercury stationary	13 40	
Sat.	22	00	Pallas stationary		
Sun.	23	04 40	● New Moon		
Mon.	24		Mercury at descending node	10 30	
		03	Moon at perigee (358,700 km)		
		03	Uranus at opposition		
Tues.	25				
Wed.	26				
Thur.	27			7 10	
Fri.	28				
Sat.	29	20 07	☽ First Quarter		
Sun.	30			4 00	
Mon.	31	13	Mars 5° S. of Moon		

[1]Visible in N. and Central S. America



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THE SKY FOR JUNE 1982

In February, we discussed the relatively rapid changes in the moon's path in the sky, due to the complex gravitational forces of the earth and sun. These same forces cause *precession*: a slow, conical motion of the rotation axis of the earth.

There are several noticeable effects of precession. One is the slow motion of the celestial poles, which are defined by the rotation axis of the earth. Polaris is presently near the north celestial pole; thousands of years from now, the north celestial pole will have moved elsewhere.

The celestial equator is also defined by the rotation axis of the earth, and will also move; its intersection points with the ecliptic (the equinoxes) will therefore also move. The vernal equinox was once in the constellation Aries (and is still called "the first point of Aries"), but it is now in Pisces. Since star positions are measured relative to the celestial equator and vernal equinox, they will gradually change due to the motion of the reference frame. The solstices, like the equinoxes, have also moved due to precession. They are no longer in Cancer and Capricorn, yet we still refer to the Tropics of Cancer and Capricorn.

The precession cycle is about 26,000 years long. It is interesting to realize that in 24,000 years, all the historical terminology will be right again!

The Sun—During June, the sun's R.A. increases from 4 h 34 m to 6 h 39 m and its Decl. changes from +21°59′ to +23°09′. The equation of time changes from +2 m 17 s to −3 m 33 s. On June 21, at 17 h 23 m U.T., the sun reaches the summer solstice, and summer begins in the northern hemisphere. There is also a partial eclipse of the sun on June 21, not visible in North America.

The Moon—On June 1.0, the age of the moon is 8.8 d. The sun's selenographic colongitude is 19.7° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on June 28 (7°) and minimum (east limb exposed) on June 15 (8°). The libration in latitude is maximum (north limb exposed) on June 16 (7°) and minimum (south limb exposed) on June 2 (7°) and June 29 (7°).

Mercury on the 1st is in R.A. 4 h 41 m, Decl. +20°05′, and on the 15th is in R.A. 4 h 22 m, Decl. +17°12′. Early in the month, it is too close to the sun to be seen (inferior conjunction occurs on the 1st). By the end of the month, it can be seen very low in the east at sunrise. Greatest elongation west occurs on the 26th. On the 23rd, it is 1.7° north of Aldebaran.

Venus on the 1st is in R.A. 2 h 00 m, Decl. +9°59′, and on the 15th it is in R.A. 3 h 03 m, Decl. +15°11′, mag. −3.4, and transits at 9 h 31 m. It rises about 1½ hours before the sun, and is very low in the east at sunrise.

Mars on the 15th is in R.A. 12 h 25 m, Decl. −2°31′, mag. +0.2, and transits at 18 h 51 m. In Virgo, it is near the meridian at sunset, and sets about 5 hours later.

Jupiter on the 15th is in R.A. 13 h 56 m, Decl. −10°29′, mag. −1.9, and transits at 20 h 21 m. In Virgo, it is almost at the meridian at sunset, and it sets shortly after midnight.

Saturn on the 15th is in R.A. 13 h 01 m, Decl. −3°42′, mag. +0.9, and transits at 19 h 26 m. In Virgo near Spica, it is near the meridian at sunset and sets at about midnight.

Uranus on the 15th is in R.A. 15 h 59 m, Decl. −20°21′, mag. +5.8, and transits at 22 h 23 m. From late June to late September, it is in Libra.

Neptune on the 15th is in R.A. 17 h 42 m, Dec. −22°03′, mag. +7.7, and transits at 0 h 10 m. From early June until late November, it is in Ophiuchus. On June 17, it is at opposition, at a distance of 29.256 astronomical units.

1982	d	h m	JUNE UNIVERSAL TIME	Min. of Algol h m	Config. of Jupiter's Satellites
Tues.	1	16	Saturn 3° S. of Moon		
		20	Mercury in inferior conjunction		
Wed.	2	21	Jupiter 4° S. of Moon	0 50	
Thur.	3				
Fri.	4		Mercury in aphelion	21 40	
Sat.	5	11	Uranus 3° S. of Moon		
Sun.	6	15 59	○ Full Moon		
Mon.	7	13	Neptune 0.3° S. of Moon; occ'n[1]	18 30	
		23	Moon at apogee (406,200 km)		
Tues.	8				
Wed.	9				
Thur.	10			15 20	
Fri.	11		Venus at greatest hel. lat. S.		
Sat.	12	09	Vesta 0.7° N. of Moon; occ'n		
Sun.	13	21	Mercury stationary	12 10	
Mon.	14	18 06	☾ Last Quarter		
Tues.	15				
Wed.	16			9 00	
Thur.	17	05	Neptune at opposition		
Fri.	18	23	Venus 2° N. of Moon		
Sat.	19	12	Saturn stationary	5 50	
Sun.	20	02	Mercury 1.1° S. of Moon; occ'n[2]		
Mon.	21		Mars at descending node		
		11 52	● New Moon; eclipse of Sun, p. 66		
		12	Moon at perigee (357,300 km)		
		17 23	Summer solstice; summer begins		
Tues.	22			2 30	
Wed.	23	03	Mercury 1.7° N. of Aldebaran		
Thur.	24		Mercury at greatest hel. lat. S.	23 20	
		06	Juno at opposition		
Fri.	25				
Sat.	26	14	Mercury greatest elong. W. (22°)		
Sun.	27			20 10	
Mon.	28	05 56	☽ First Quarter		
		08	Jupiter stationary		
		12	Mars 6° S. of Moon		
		21	Saturn 3° S. of Moon		
Tues.	29	21	Vesta stationary		
Wed.	30	01	Jupiter 4° S. of Moon	17 00	

[1]Visible in S.E. Asia and the Pacific
[2]Visible in N. Asia, the N. of N. America, and the Arctic

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ECLIPSES DURING 1982

In 1982 there will be seven eclipses, four of the Sun and three of the Moon. Two of these, the total lunar eclipses of July 6 and December 30, are of special interest to observers in North America. Such an eclipse was last visible from the central and western portions of North America in 1979; however, it has been seven years since observers in eastern North America have been treated to the ethereal beauty of a total lunar eclipse. For a description of several visual and photographic observations that can be made of a lunar eclipse, see *Sky and Telescope*, May 1975, pages 280–283.

1. *January 9: Total Eclipse of the Moon*
   This is generally visible from the Eastern Hemisphere and Arctic regions, although the beginning of the umbral phase is visible from extreme northwestern North America, and the end from extreme northeastern North America. Magnitude of eclipse* = 1.337

Moon enters penumbra	17^h	14.8^m	UT
Moon enters umbra	18	13.6	
Total eclipse begins	19	16.6	
Middle of eclipse	19	55.8	
Total eclipse ends	20	35.0	
Moon leaves umbra	21	38.1	
Moon leaves penumbra	22	36.9	

2. *January 25: Partial Eclipse of the Sun*
   Visible from New Zealand and Antarctica.
3. *June 21: Partial Eclipse of the Sun*
   Visible from southern Africa.
4. *July 6: Total Eclipse of the Moon*
   Visible in North America, except the Arctic regions. Also, the last portion of totality is not visible from extreme northeastern North America. Visible also from South America, Antarctica, and the Pacific Ocean. Magnitude of eclipse* = 1.722

Moon enters penumbra	04^h	22.2^m	UT
Moon enters umbra	05	32.8	
Total eclipse begins	06	37.7	
Middle of eclipse	07	30.9	
Total eclipse ends	08	24.1	
Moon leaves umbra	09	29.0	
Moon leaves penumbra	10	39.6	

5. *July 20: Partial Eclipse of the Sun*
   Visible from western Europe, Greenland, the Arctic islands, and northeastern Asia.
6. *December 15: Partial Eclipse of the Sun*
   Visible from Europe, northeastern Africa, and western Asia.
7. *December 30: Total Eclipse of the Moon*
   Visible from North America and several other areas, including the Arctic regions and the Pacific. Magnitude of eclipse* = 1.188

Moon enters penumbra	08^h	51.9^m	UT
Moon enters umbra	09	50.4	
Total eclipse begins	10	58.2	
Middle of eclipse	11	28.7	
Total eclipse ends	11	59.3	
Moon leaves umbra	13	07.0	
Moon leaves penumbra	14	05.5	

*The magnitude of a partial or total lunar eclipse is the fraction of the lunar diameter within the umbra of Earth's shadow at greatest phase, measured along the common diameter.

METEORS AND COMETS

METEORS, FIREBALLS AND METEORITES

BY PETER M. MILLMAN

Meteoroids are small solid particles moving in orbits about the Sun. On entering the Earth's atmosphere they become luminous and appear as meteors or fireballs, and in rare cases, if large enough to avoid complete fragmentation and vaporization, they may fall to the Earth as meteorites.

Meteors are visible on any night of the year. At certain times of the year the Earth encounters large numbers of meteoroids all moving together along the same orbit. Such a group is known as a meteor stream and the visible phenomenon is called a meteor shower. The orbits followed by these meteor streams are very similar to those of short-period comets, and in many cases can be identified with the orbits of specific comets.

The radiant is the position among the stars from which the meteors of a given shower seem to radiate. This is an effect of perspective commonly observed for any group of parallel lines. Some showers, notably the Quadrantids, Perseids and Geminids, are very regular in their return each year and do not vary greatly in the numbers of meteors seen at the time of maximum. Other showers, like the Leonids, are very unpredictable and may arrive in great numbers or fail to appear at all in any given year. The δ Aquarids and the Taurids are spread out over a fairly extended period of time without a sharp maximum.

For more information concerning meteor showers, see the paper by A. F. Cook in "Evolutionary and Physical Properties of Meteoroids", NASA SP-319, pp. 183–191, 1973.

An observer located away from city lights and with perfect sky conditions will see an overall average of seven sporadic meteors per hour apart from the shower meteors. These have been included in the hourly rates listed in the table. Slight haze or nearby lighting will greatly reduce the number of meteors seen. More meteors appear in the early morning hours than in the evening, and more during the last half of the year than during the first half.

When a meteor has a luminosity greater than the brightest stars and planets it is generally termed a fireball. The appearance of any very bright fireball should be reported immediately to the nearest astronomical group or other organization concerned with the collection of such information. Where no local organization exists, reports should be sent to Meteor Centre, Herzberg Institute of Astrophysics,

MAJOR VISUAL METEOR SHOWERS FOR 1982

Shower	Shower Maximum Date	U.T.	Moon	Radiant Position at Max. R.A.	Dec.	Daily Motion R.A.	Dec.	Single Observer Hourly Rate	Speed	Normal Duration to ½ Strength of Max.
		h		h m	°	m	°		km/s	days
Quadrantids	Jan. 3	19	FQ	15 28	+50	—	—	40	41	1.1
Lyrids	Apr. 22	14	NM	18 16	+34	+4.4	0.0	15	48	2
η Aquarids	May 4	20	FM	22 24	00	+3.6	+0.4	20	65	3
S. δ Aquarids	July 28	23	FQ	22 36	−17	+3.4	+0.17	20	41	7
Perseids	Aug. 12	13	LQ	03 04	+58	+5.4	+0.12	50	60	4.6
Orionids	Oct. 21	18	FQ	06 20	+15	+4.9	+0.13	25	66	2
S. Taurids	Nov. 2	18	FM	03 32	+14	+2.7	+0.13	15	28	—
Leonids	Nov. 17	12	NM	10 08	+22	+2.8	−0.42	15	71	—
Geminids	Dec. 14	10	NM	07 32	+32	+4.2	−0.07	50	35	2.6
Ursids	Dec. 22 (1983)	19	FQ	14 28	+76	—	—	15	34	2
Quadrantids	Jan. 4	01	LQ	15 28	+50	—	—	40	41	1.1

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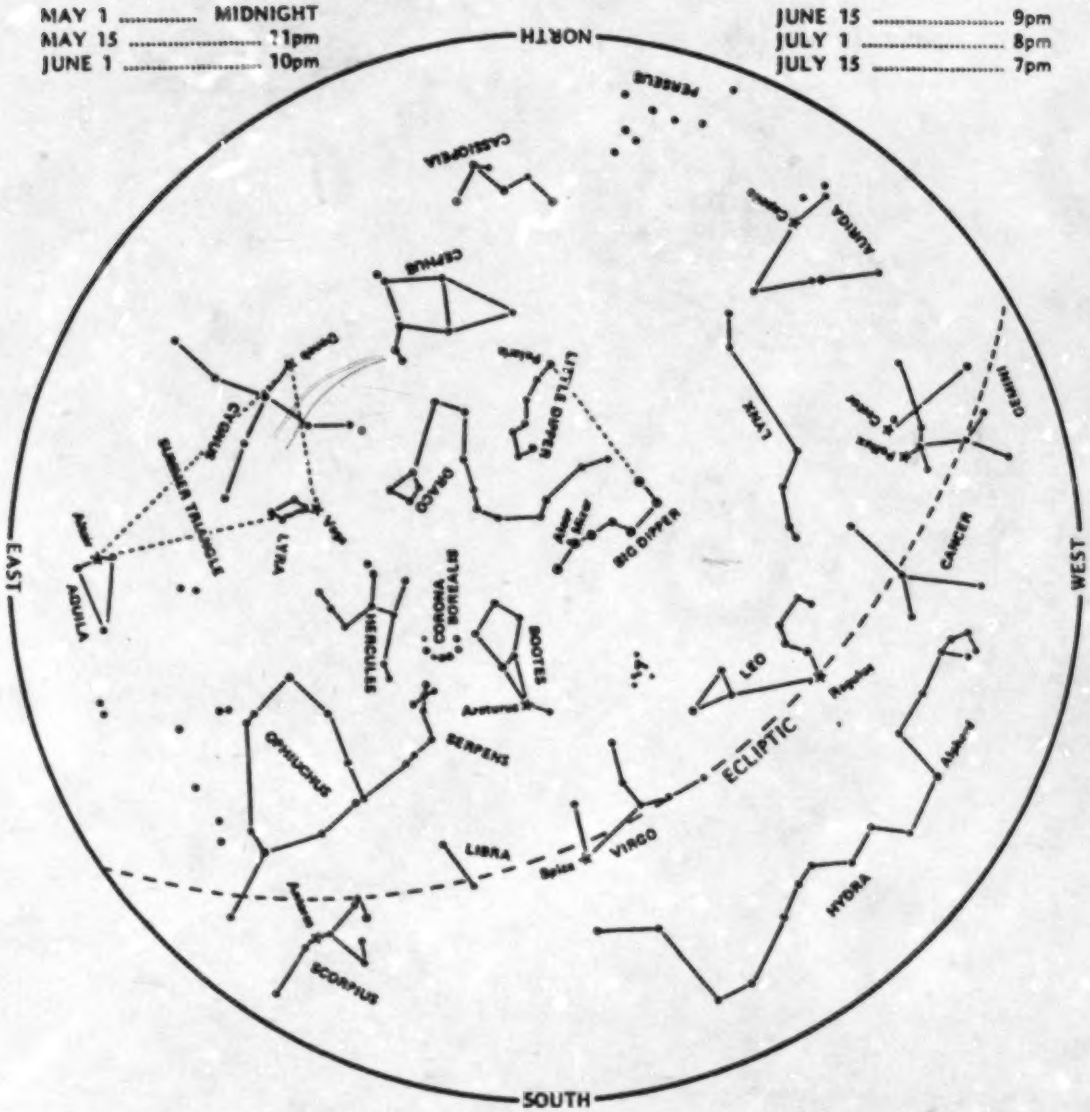
SPRING STARS

THIS STAR MAP WILL WORK BEST AT THESE TIMES:

MAY 1 ..... MIDNIGHT
MAY 15 ..... 11pm
JUNE 1 ..... 10pm

JUNE 15 ..... 9pm
JULY 1 ..... 8pm
JULY 15 ..... 7pm



Hold the map overhead and turn it so that the directions marked around the map's horizons match the true directions. Try and find the brightest stars and constellations first, then the fainter ones. If any planets are visible they will look like bright stars. Planets are always found close to the ecliptic.

The objects marked like ✸ M13 are objects such as galaxies, nebulae or star clusters. Under a dark country sky most of these can be observed with the eye alone. They are best observed with binoculars or a telescope.

For more information about sky watching, consult *The Sky Observers Guide* by Mayall, Mayall, and Wyckoff, The Golden Press, New York, 1965. A star map that will work all year, at any hour, is *Philip's Planisphere*. These and other helpful publications are available at the Museum Bookstore.

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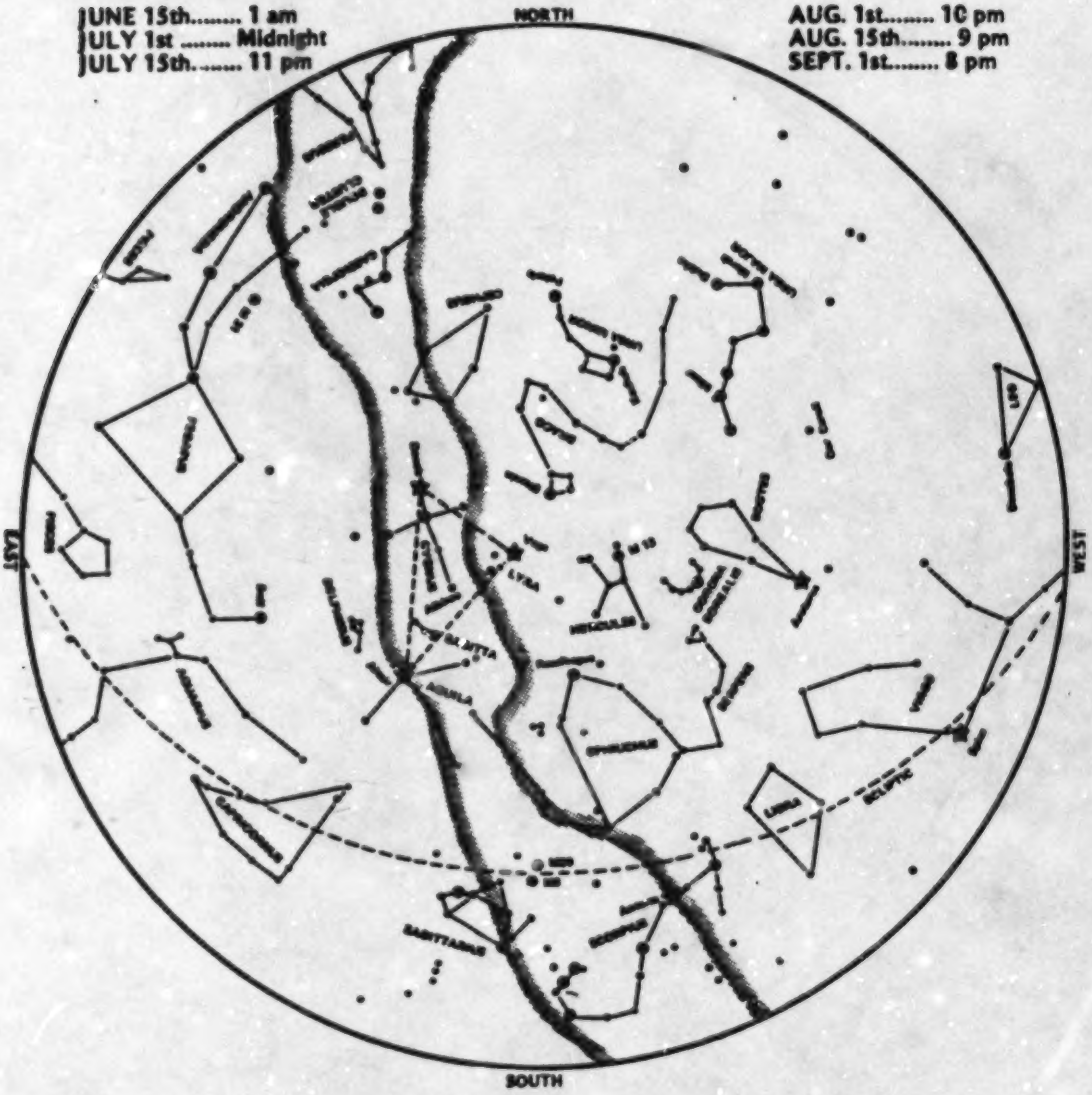
SUMMER STARS

This star map will work best at these times:

JUNE 15th..... 1 am
JULY 1st ..... Midnight
JULY 15th..... 11 pm

AUG. 1st..... 10 pm
AUG. 15th..... 9 pm
SEPT. 1st..... 8 pm



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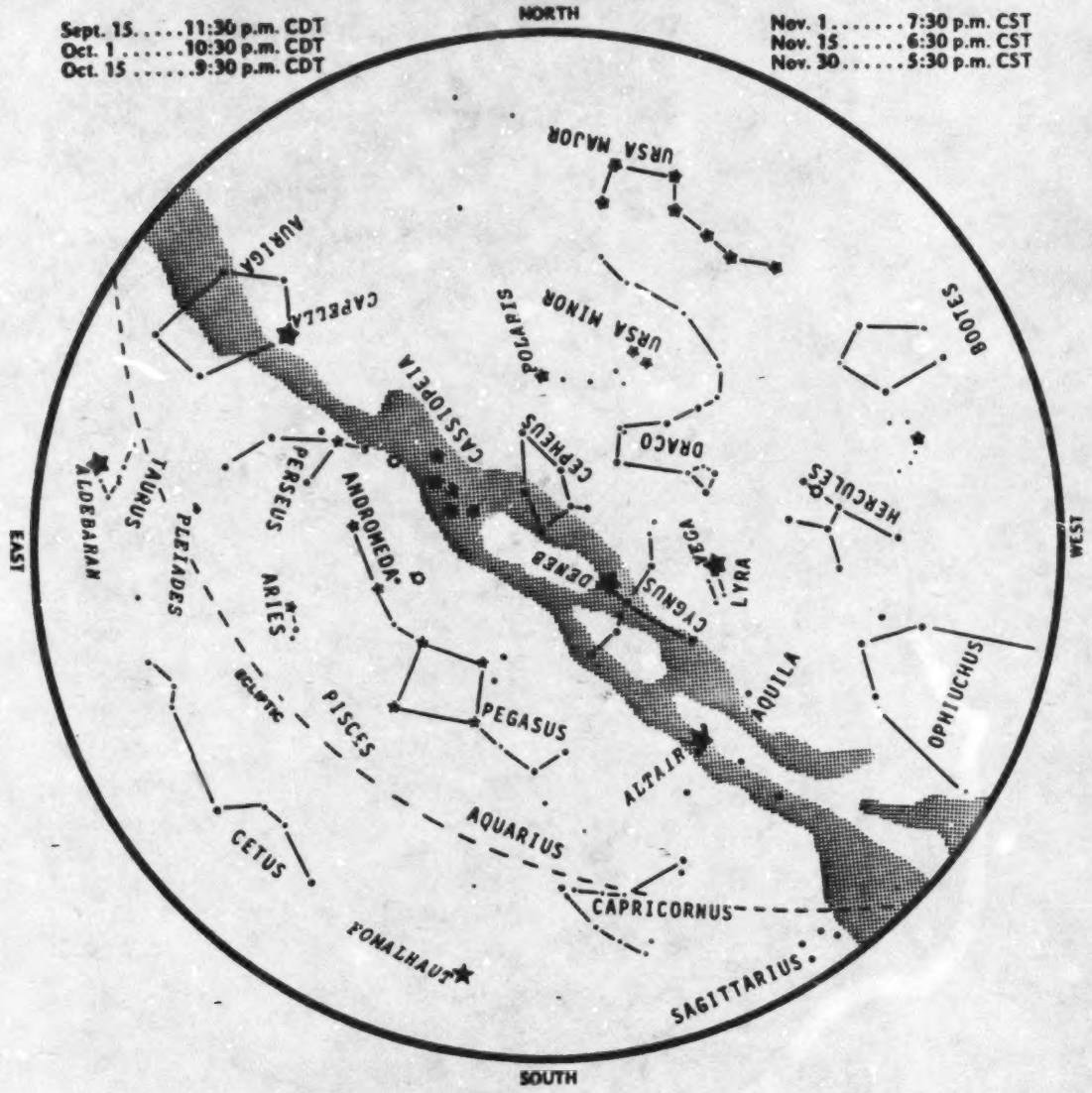
AUTUMN STARS

THIS STAR MAP WILL WORK BEST AT THESE TIMES:

Sept. 15.....11:30 p.m. CDT
Oct. 1.....10:30 p.m. CDT
Oct. 15.....9:30 p.m. CDT

Nov. 1.....7:30 p.m. CST
Nov. 15.....6:30 p.m. CST
Nov. 30.....5:30 p.m. CST



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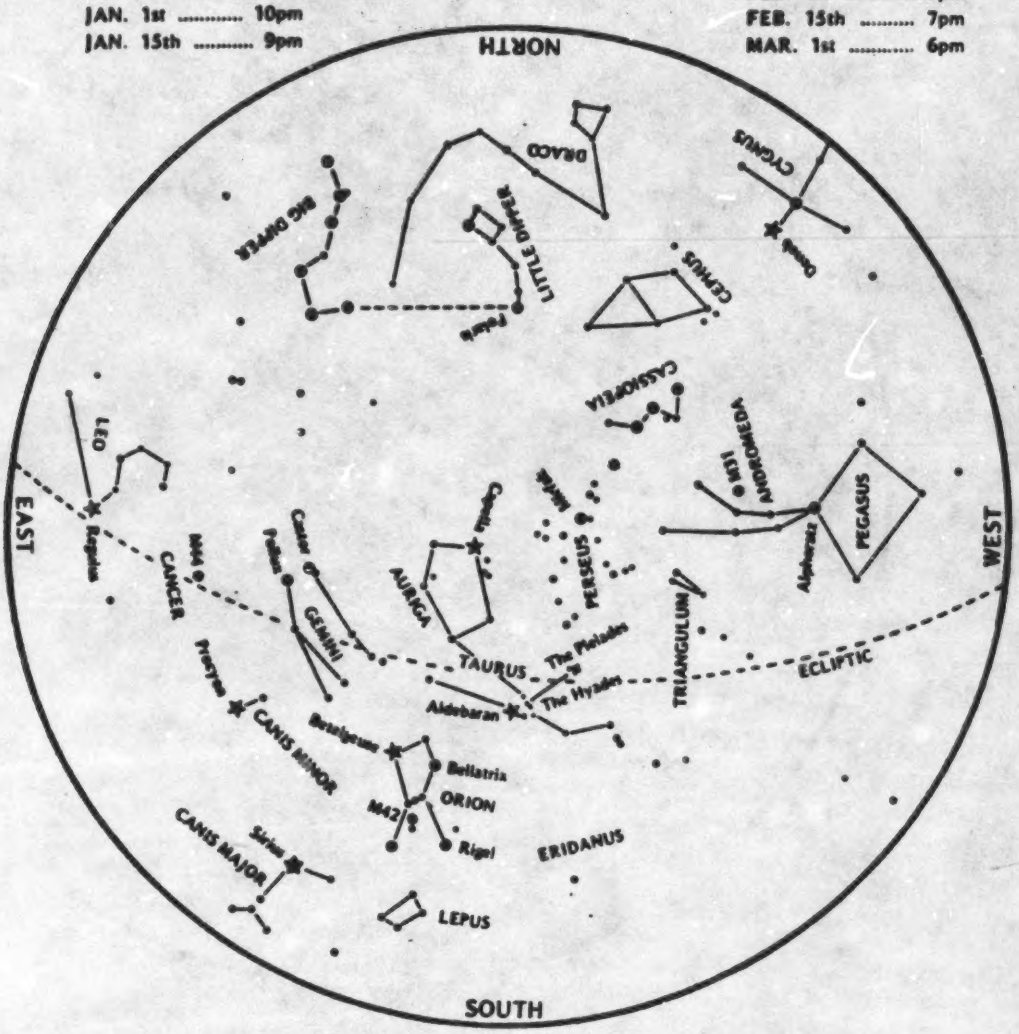
WINTER STARS

THIS STAR MAP WILL WORK BEST AT THESE TIMES:

DEC. 15th 11pm
JAN. 1st 10pm
JAN. 15th 9pm

FEB. 1st 8pm
FEB. 15th 7pm
MAR. 1st 6pm



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CELESTIAL COORDINATE SYSTEM

CELESTIAL SPHERE	AN IMAGINARY SPHERE OF INFINITE RADIUS SURROUNDING THE EARTH AND SERVING AS A SCREEN AGAINST WHICH ALL CELESTIAL OBJECTS ARE SEEN.
RIGHT ASCENSION	THE ANGULAR DISTANCE FROM THE PRIME MERIDAN TO A CELESTIAL BODY MEASURED EASTWARD ALONG THE CELESTIAL EQUATOR FROM 0 DEGREES TO 360 DEGREES, OR FROM 0 TO 24 HOURS. ANALOGOUS TO LONGITUDE IN GEOGRAPHY.
DECLINATION	ANGULAR DISTANCE OF AN OBJECT FROM THE CELESTIAL EQUATOR, MEASURED IN DEGREES, MINUTES AND SECONDS. ANALOGOUS TO LATITUDE IN GEOGRAPHY.

FIND 5 NORTH POLAR CONSTELLATIONS

A T A R C F G D D S N L

I X H W E O H R O H D R

D M G U P P R H B I A O

R O L M H O P O T L I I

V I M G E C H I M R E A

W H C E U A C N D H P F

S F O W S R O E D G O A

R E P P I D E L T T I L

D H E Y Y O T W U H S B

R L F T Y C C O Y R S N

K M U N X H L D A R A Y

I U K M C S S A R A C S

BIGDIPPER

CASSIOPEIA

CEPHEUS

DRACO

LITTLEDIPPER

FIND 9 PLANETS

A N W D N S F F T M Q

A A U D N U C O W A S

C E B F D N U M L S R

H O O C V A P E Y U A

O T T T O R N L F N M

F U R L H U L K S E C

L L S A T U R N R V H

E P T P E Y Y C Z S R

R R E T I P U J N M H

Q N Z P T R W Z L R T

R O B H Y Z I D A S L

EARTH

JUPITER

MARS

MERCURY

NEPTUNE

PLUTO

SATURN

URANUS

VENUS

FIND 12 CONSTELLATIONS OF THE ZODIACS

M H R S A H L S N M S I I E R D S Z

L R A D F S A E R U F X E S M T J Y

A S M D K Y C T O E A Y E L J D Y N

W S A H S A M H C G T C S S C U L T

T A M B H U A R I Y S E M A U R D U

T E E U D T R N R I I P N D D G A R

A O E N L T U U P R D L B D S T D R

N V D D G A T S A G I T T A R I U S

H L R X M N H Q C T S D S A U N E T

G Z I C A P U A E O D C G T T G E F

O E N B E A N N S U R H J A V T T Y

F O M V R C M U F U D P N O Y O L C

H B I I E A I F X F R O I G C A Y U

N E U R N D E A R O H E D O A W S I

M S A G W I V H E K H A S S T O U B

T D C O S I L B N P F N N Y I B R P

AQUARIUS

ARIES

CANCER

CAPRICORN

GEMINI

LEO

LIBRA

PISCES

SAGITTARIUS

SCORPIO

TAURUS

VIRGO

FIND 15 STARS

V E A L T F D G A N M S I R I U S A

D Y D G U D D O I T S I Y M I J Z Y

Z R D R A Q N N A T I R I S K G T E

B W H W N W A Y C U H A U H P E E Q

B A N I R O D A Q O E L R G W S E L

T M H R E W N N A P U O Z N S N R N

B S T N X S C D S G L P A S A D O H

L E T S A R E A E U W U I S U N Y N

E U N O Y C O R P B T K M Y M S A S

C N H E I A E W A E F T N L V A A I

U A I D D D N P B T L P S E E C T A

U E E G H C C L O E N L G P N E U B

R H N A R A B E D L A A A L C M F D

P U U N T S F U X G L O L R A F W O

B E O I P T Q H A E F U U T L I D F

Y N E I I O D F U U T A X F A W R N

S D C F D R R N S S E B T I E I J H

E A V M U Y U K N E J X E S V A R R

ALDEBARAN

ALTAIR

ANTARES

BETELGEUSE

CAPELLA

CASTOR

DENEB

POLARIS

POLLUX

PROCYON

REGULUS

RIGEL

SIRIUS

SPICA

VEGA

FIND 15 HAPPENINGS IN THE SOLAR SYSTEM

R B F H A L O L C O I N S

G S X X I I D O S U T B N

P X J N J F M L Y A A L Y

D H K S Y E B U S L A N W

H G A S T D I U E Y V H J

N C D S R E F N T E F D H

K A R P E O N I I O G L M

P A F A Y S E A L N E N C

T E M S T T L T L H E B N

D I M G M E I U E P I W E

H R L N T A R V T M D H W

S D I O R E T S A B O E W

H H S O I R G U S R C N N

D M R I M N I N G L G M R

O Y A T I Y A S I H N R A

A I T R I L D P Q C N U F

X G F G E W S O R B I T S

M Y N T R E G T A T E M M

O H M U N L L S N D Z H E

ASTEROIDS
COMETS
CRATERS
ECLIPSE
GRAVITY
LIFE
MARE
METEORS
ORBITS
PHASES
PLANETS
RINGS
SATELLITES
SUN
SUNSPOTS

FIND 14 HAPPENINGS OUTSIDE THE SOLAR SYSTEM

S A E F Z K N K B C A O N A S D L I M P D E O I T H E N R
T I M Y I C H C Y J R W A S T T S S T T E F P E K C O N T
F F T D C W B M M T O M L W A I N I E N R I F O W N D Y G
T F M O D Q D A S G A S O E R M I A P D K Y B V F J N I A
H O H P A S O E E V O P Q M S M B R I N A Y S M D E C U H
I N N A A O L A E H C N T O D E S A E G L C S I C N I O E
O N O Y O M O D P S W S D S X C A W U P D N I L H N B F U
G H T M O T F S R A D H D A R A T N H M O E T K U O M C F
V H T H D I K D Z L O S M F N S N N B I N A R Y S T A R S
A N D H F E I R U E K O O E D D G P T S T W H W E D A Q I
W S D C O T L E I A D E M O R D N A E L L E E A H H L Z E
H R N E P N E D S S U H K X B B L O L D D K D Y O Y C Z T
H I F G X F U Y F R B O A Y S L N R V A T O S W S H S S T
D N N T N F W H U A E B L U E U A Q A A X I C U A E H C Z
M R N M T O T R E S L T Q T P E Q C H W E I B T L R U R N
L N B E G O H L H A P T S O A G T X K Y T C E E O F F B A
S R A T S N O R T U E N U N U I T E O H F G C S T O F S U
I J L X R T Q L L Q O D G M R A S T W L O B K O W P S X L
U O P H H T O S N C T T S F C N F T A N Y L N R A M H E N
K E E F A T A L P G O H T N T T H U T N L Q E E N O Y Q D
A E E I R R H K S D M D T A F S A R H E S T Q S K H M R B
G Z H R S E J D P G R X I P H U F W U K O M E D G L U R T

ANDROMEDA
BINARYSTARS
BLACKHOLES
BLUEGIANTS
CONSTELLATIONS
GALAXIES
MILKYWAY
NEUTRONSTARS
NOVAE
PULSARS
QUASARS
REDGIANTS
STARS
WHITEDWARFS

DOES YOUR BIRTH SIGN AFFECT YOUR TEACHING STYLE?

Is astrology a semi-science or a pseudo-science? Most people enjoy reading horoscopes; even teachers dedicated to the rational and provable often sneak looks. If it's true that your personality is influenced by the sign of the zodiac under which you were born, so is the way you teach. Do you find yourself or fellow teachers here?

ARIES (March 21-April 19) The Aries teacher tends to be active and colorful. He may prefer to teach physical education or coach; in any case, his students should be good at sports. He is an inspiring teacher who likes to flash ahead, sometimes leaving slower thinkers behind. Aries natives give generously of their time and energy. They make good team leaders because of their enthusiastic attack on problems and their management ability.

TAURUS (April 20-May 20) The Taurus group is deliberate and slow paced. These people are practical, yet they value beautiful possessions and are creative in a methodical way. Although a Taurean takes all his responsibilities seriously, he will shine in teaching math and economics on one hand, aesthetics on the other. He is most comfortable when he feels secure in his job.

GEMINI (May 21-June 21) A Gemini native is many-faceted and dexterous. He finds repetitive teaching boring, and discovers as many interesting ways as possible to present his wide knowledge. Geminis are interesting and entertaining to students and colleagues. They tend to be communications experts, making good English teachers and faculty coordinators of the school newspaper.

CANCER (June 22-July 22) The teacher, either male or female, who is like a mother hen with her brood is most likely to be a Cancer, and thus most likely to function best in kindergarten or the primary grades. They are good craftsmen with a tendency to be romantic about the past. Thus, they may be equally at home in teaching either home economics or history. They may be moody with friends but warm and sympathetic with children.

LEO (July 23-August 22) Leo teachers do well in open education. These self-assured people prefer to inspire rather than to direct. They are not good at details or much concerned with them. They often have an outside income or a financially successful husband. The Leo's strong, magnetic personality exerts a broad influence over his students, on whose admiration he thrives.

VIRGO (August 23-September 22) Virgos like to work with both their hands and their heads. They enjoy solving knotty problems, especially when they feel they are helping other people. They are meticulous, and like to feel that everything is under control. The Virgo teacher is anxious to pass his knowledge on to the students and can discuss even sensitive subjects with composure. Virgo's passion for perfection often drives students to work at maximum abilities. And the results

often surprise the students themselves. Because Virgos tend to be more impersonal, they are better fitted to upper elementary teaching.

LIBRA (September 23-October 23) Harmonious relationships with students are an emotional necessity for Libra teachers. Because of this, their classes work smoothly and efficiently. The complete range of subjects is carefully interrelated. A Libran is often gifted in art and music. His energy level is not big, but a firm pleasant manner usually wins help and cooperation.

SCORPIO (October 24-November 21) A Scorpio is an imaginative teacher, with curiosity and an excellent memory, who likes to explore subjects in depth. He may seem aloof to fellow teachers but the children recognize his deep devotion to them. Summers and weekends are likely to find a Scorpio native, male or female, flirting with danger in such activities as running the rapids or sky-diving. Scorpios are good at handling extensive changes or potentially explosive situations. Because Scorpios love to be surrounded by diversified groups of people, they are particularly suited for ethnically or socioeconomically mixed schools.

SAGITTARIUS (November 22-December 21) The Sagittarian is big, adaptable, and a seeker of truth, asking questions until he is satisfied. He believes in sportsmanship, and expects students to pay attention to their work. His bluntness of speech is well accepted by the children because it lets them know just where they stand. Sagittarians love to travel and may be attracted to teaching because it allows time to do it.

CAPRICORN (December 22-January 19) A Capricorn native is a natural supervisor, preferably of large groups. He is well prepared to teach all subjects, with an excellent fund of traditional knowledge. He'll be the one to organize a musical group and after-school sports. Capricorns are strict in class, but are likely to work on their own time with a child having trouble learning. Their stern demeanor doesn't fool the children.

AQUARIUS (January 20-February 18) Aquarian teachers probably function best in open education. They are inventive, and love to be free to try what is new. Since an Aquarian doesn't care about security, he may be found in one of the new "alternative" schools. He is witty and humorous and runs an exciting class.

PISCES (February 19-March 20) When a Piscean is a teacher, it is because of the opportunity to serve mankind. He is sympathetic with children's problems, in fact he may be oversensitive and overly conscientious to the point of injuring his health. Pisceans are intuitive and imaginative; they like to play roles and teach children to do so. Because of their excellent ability to dramatize, a Piscean teacher can captivate children in ordinarily routine learning situations. Pisces natives often take on tasks no one else wants!